Bangladesh Technology Verification Application
Kanchan Arsenic Filter

Tom Mahin - MIT/CAWST
Tommy Ngai - CAWST

Presented at the Centre for Affordable Water and Sanitation Technology (CAWST) Learning Exchange – Calgary, Canada June 2008
Arsenic mitigation for safe groundwater

Report by the Secretariat

• 12 countries in Asia currently ….are exceeding permissible levels, with at least 50 million people exposed to levels exceeding 50 μg/l.”

• “In Latin America it is estimated that at least four million people are exposed to high concentrations of arsenic in drinking-water, primarily rural dwellers consuming water from wells in affected countries, including Argentina, Bolivia, El Salvador, Mexico, Nicaragua and Peru”.
Modeled global probability of arsenic contamination in groundwater for (a) reducing groundwater conditions, and (b) high-pH/oxidizing conditions.

From Amini et al., _E, S & T_ (March 2008)
### TABLE 4. State of Arsenic Contamination in Groundwaters in Different Countries of the World

<table>
<thead>
<tr>
<th>Country</th>
<th>Condition</th>
<th>% Area&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bangladesh (2)</td>
<td>reducing</td>
<td>35.4</td>
</tr>
<tr>
<td>Cambodia (25, 26)</td>
<td>reducing</td>
<td>45.8</td>
</tr>
<tr>
<td>Vietnam (8, 9, 25)</td>
<td>reducing</td>
<td>15.3</td>
</tr>
<tr>
<td>Taiwan (27)</td>
<td>reducing</td>
<td>8.2</td>
</tr>
<tr>
<td>Nepal (28)</td>
<td>reducing</td>
<td>3.2</td>
</tr>
<tr>
<td>Romania (29)</td>
<td>reducing</td>
<td>3.5</td>
</tr>
<tr>
<td>USA (7, 10, 23)</td>
<td>both</td>
<td>8.3</td>
</tr>
<tr>
<td>Argentina (30)</td>
<td>oxidizing</td>
<td>4.9</td>
</tr>
<tr>
<td>India (31)</td>
<td>both</td>
<td>6.4</td>
</tr>
<tr>
<td>China (4, 32)</td>
<td>both</td>
<td>2.5</td>
</tr>
<tr>
<td>Hungary (29)</td>
<td>reducing</td>
<td>7.4</td>
</tr>
<tr>
<td>Finland (33)</td>
<td>unknown</td>
<td>34.7</td>
</tr>
<tr>
<td>Greece (34)</td>
<td>unknown</td>
<td>0.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Country</th>
<th>Condition</th>
<th>% Area&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estonia</td>
<td>reducing</td>
<td>37.2</td>
</tr>
<tr>
<td>Amazon basin&lt;sup&gt;a&lt;/sup&gt;</td>
<td>reducing</td>
<td>32.6</td>
</tr>
<tr>
<td>Lithuania</td>
<td>both</td>
<td>35.0</td>
</tr>
<tr>
<td>Congo</td>
<td>reducing</td>
<td>30.1</td>
</tr>
<tr>
<td>Russia</td>
<td>both</td>
<td>14.8</td>
</tr>
<tr>
<td>Myanmar</td>
<td>both</td>
<td>9.2</td>
</tr>
<tr>
<td>Poland</td>
<td>both</td>
<td>8.8</td>
</tr>
<tr>
<td>Cameroon</td>
<td>both</td>
<td>14.0</td>
</tr>
<tr>
<td>Ukraine</td>
<td>oxidizing</td>
<td>7.0</td>
</tr>
<tr>
<td>Byelarus</td>
<td>oxidizing</td>
<td>3.3</td>
</tr>
<tr>
<td>Zambia</td>
<td>oxidizing</td>
<td>7.0</td>
</tr>
<tr>
<td>Nigeria</td>
<td>oxidizing</td>
<td>9.0</td>
</tr>
<tr>
<td>Angola</td>
<td>oxidizing</td>
<td>5.5</td>
</tr>
<tr>
<td>Kenya</td>
<td>oxidizing</td>
<td>2.4</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>oxidizing</td>
<td>5.3</td>
</tr>
</tbody>
</table>

<sup>a</sup> Average values for Peru, Brazil, and Colombia. <sup>b</sup> % Area in each country with probability of arsenic contamination >0.75.
Arsenic in Asia

From: World Bank “Study: Arsenic Contamination of Groundwater in South and East Asian Countries” 2005
Arsenic Levels in Groundwater in Bangladesh

Drinking Water Standards
Bangladesh – 50 ug/L
WHO – 10 ug/L
Percent of Wells > 50 ug/L of Arsenic (Bangladesh Standard)
Average Arsenic Concentrations in Wells by District

Figure 4. District-wise average arsenic concentration (in µg L⁻¹) found from the DPHE/BGS National Hydrochemical Survey.

BGS AND DPHE, 2001
Arsenic contamination of groundwater in Bangladesh
KINNIBURGH, D G and SMEDLEY, P L (Editors)
Volume 1: Summary
British Geological Survey Report WC/00/19
British Geological Survey, Keyworth.
Contamination of drinking-water by arsenic in Bangladesh: a public health emergency

Allan H. Smith, Elena O. Lingas, & Mahfuzar Rahman

Bulletin of the World Health Organization, 2000, 78 (9)

The contamination of groundwater by arsenic in Bangladesh is the largest poisoning of a population in history, with millions of people exposed. This paper describes the history of the discovery of arsenic in drinking-water in Bangladesh and recommends intervention strategies. Tube-wells were installed to provide “pure water” to prevent morbidity and mortality from gastrointestinal disease. The water from the millions of tube-wells that were installed was not tested for arsenic contamination. Studies in other countries where the population has had long-term exposure to arsenic in groundwater indicate that 1 in 10 people who drink water containing 500 µg of arsenic per litre may ultimately die from cancers caused by arsenic, including lung, bladder and skin cancers. The rapid allocation of funding and prompt expansion of current interventions to address this contamination should be facilitated. The fundamental intervention is the identification and provision of arsenic-free drinking water. Arsenic is rapidly excreted in urine, and for early or mild cases, no specific treatment is required. Community education and participation are essential to ensure that interventions are successful; these should be coupled with follow-up monitoring to confirm that exposure has ended. Taken together with the discovery of arsenic in groundwater in other countries, the experience in Bangladesh shows that groundwater sources throughout the world that are used for drinking-water should be tested for arsenic.

“1 in 10 people who drink water containing 500 µg/L of arsenic may ultimately die from cancers caused by arsenic including lung, bladder and skin cancers” - WHO
Box 2. Long-term health effects of exposure to arsenic

Skin lesions
Skin cancer
Internal cancers
  Bladder
  Kidney
  Lung
Neurological effects
Hypertension and cardiovascular disease
Pulmonary disease
Peripheral vascular disease
Diabetes mellitus
Scale of the Arsenic Problem in Bangladesh

• Bangladesh Drinking Water Standard – 50 ug/L (ppb).
• Approximately 8 million drinking water wells (tubewells) in Bangladesh.
• 20 million people potentially impacted (current UNICEF estimate).
Countries by Population Density

From Wikipedia
The World’s Largest River Delta

Most of Bangladesh lies within the world’s largest river delta formed by 3 rivers (Ganges, Brahmaputra, and Meghna) and is subject to annual flooding during the monsoon season. Large quantities of fertile soil is deposited by the floodwaters. Most of the land in Bangladesh is extremely flat and low-lying.
Figure 3. Illustration of the widely accepted theory on the origin of arsenic in groundwater of tropical and subtropical river deltas.

1. Adsorption of arsenic to iron(hydr)oxide coatings on particle
2. Deposition of arsenic containing sediments
3. Arsenic release triggered by microbial activity & dissolution of iron(hydr)oxide

Fine grained sediments such as iron oxides travel furthest downstream.

Organic material deposited by rivers uses up oxygen leading to release of As from sediments in groundwater.

Iron oxides are formed from weathering of primary minerals (biotite etc.) and oxidation of Fe^{2+}.

Iron-rich sediments strongly sorb As under oxidizing conditions.

Very low/flat hydraulic gradients lead to very slow groundwater movement, As accumulates.

Adapted from:
BGS AND DPHE, 2001
Arsenic contamination of groundwater in Bangladesh
KINNIBURGH, D G and SMEDLEY, P L (Editors)
Volume I: Summary
British Geological Survey Report WC/00/15
British Geological Survey, Keyworth.
Why Are Arsenic Levels So High in Bangladesh Wells?

- High arsenic levels in groundwater in Bangladesh are a function of hydrogeology & groundwater chemistry of Bengal Basin not the levels of As in sediments.

- Levels of As in sediments are similar to many other parts of the world.

**Figure 12.7** above from:

BGS AND DPHE, 2001
Arsenic contamination of groundwater in Bangladesh
KINNIBURGH, D G and SMEDLEY, P L (Editors)
Volume 1: Summary
British Geological Survey Report WC/00/19
British Geological Survey, Keyworth.

**Figure 12.7.** Schematic diagram showing how the consequences of a high solid/solution ratio on pore water arsenic concentrations. Complete dissolution of even small amounts of arsenic (1 mg kg\(^{-1}\) here) from a sandy Bangladesh aquifer sediment would give rise to extremely high concentrations of arsenic in the groundwater.
Comparison of Dissolved As in Groundwater vs. As in Solid Phase (sediments in the aquifer)

From Harvey – MIT OpenCourseWare at http://dspace.mit.edu
Reduction in oxygen in groundwater causes As\(^{+5}\) to be converted to As\(^{+3}\) which is the more mobile form.
Figure 2.3  Arsenic concentration of groundwater in tube-wells from the DPHE/BGS National Hydrochemical Survey plotted as a function of tube-well depth (Kinniburgh & Smedley 2001)
Arsenic Removal Technology Verification

Bangladesh

- The Governments of Canada and Bangladesh established a technology verification project to help Bangladesh develop and implement a scientifically defensible method for validating arsenic removal performance claims by technology proponents.

- The Bangladesh Council of Scientific & Industrial Research (BCSIR) was designated as the verification authority.

- The Ontario Centre for Environmental Technology Advancement (OCETA) in Canada is working with BCSIR.
Basic Technology Verification Concepts

Technology verification for water treatment for chemical contaminants is based on:

1. Field testing under actual field use conditions (not laboratory conditions) by a neutral third party.

2. Identifying the range of situations under which a technology will work as designed (maximum pH, maximum phosphate levels, etc.).
Project Partners for Field Testing of Kanchan Arsenic Filter (KAF) for Certification Application in Bangladesh

• LEDARS – Highly motivated NGO from SW Bangladesh.
• CAWST (Centre for Affordable Water & Sanitation Technology).
• Massachusetts Institute of Technology (MIT).
• ENPHO – Provided supporting activities such as training & initial plastic filters.
Overview of Kanchan Arsenic Filter Pilot Study

Bangladesh

- 8 KAF filters tested in 2 different districts in Bangladesh prior to submittal of certification application.
- Some sampling was done by test kits but most all of the samples were by laboratory analysis by AAS at Asia Arsenic Network (AAN) lab in Jessore. Split lab sample taken to AAN and DPHE lab (Khulna).
- 5 sampling rounds (March – Dec. 2007).
- Certification testing expected to start in August 2008.
Bangladesh Project Team

- **Mohon Mondal** (LEDARS-Bangladesh) – Responsible for filter construction, logistics and project oversight.
- **Tommy Ngai** (CAWST) – Advisor & developed KAF with ENPHO while grad student at MIT.
- **Susan Murcott** (MIT) – Advisor & project financial support for LEDARS.
- **Bipin Dongal** (ENPHO & UN HABITAT) – Involved in developing KAF & provided KAF training in Nepal.
- **Tom Mahin** (MIT/CAWST) - Project coordinator.
Portion of Satkhira District included in CAWST/MIT pilot study

Arsenic Levels in Satkhira District
(BGS/DPHE data)

Arsenic Concentration (µg/L)
- < 10
- 10 - 50
- 50 - 100
- 100 - 250
- > 250
- Wells deeper than 150m

Government of the People’s Republic of Bangladesh
Ministry of Local Government, Rural Development and Cooperatives
Department of Public Health Engineering

ARSENIC IN GROUNDWATER IN BANGLADESH

Groundwater Studies of Arsenic Contamination in Bangladesh
British Geological Survey
Funded by
Department for International Development, UK
March 2000
**Example of Part of Satkhira District Where We Work**

<table>
<thead>
<tr>
<th>Village</th>
<th># of TW</th>
<th>Safe TW</th>
<th>Conta. TW</th>
<th>% Conta.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chandanpur</td>
<td>12</td>
<td>116</td>
<td>2011</td>
<td>94.55</td>
</tr>
<tr>
<td>Diara</td>
<td>8</td>
<td>179</td>
<td>1867</td>
<td>91.25</td>
</tr>
<tr>
<td>Helathala</td>
<td>13</td>
<td>19</td>
<td>1434</td>
<td>98.69</td>
</tr>
<tr>
<td>Jallabad</td>
<td>11</td>
<td>44</td>
<td>1493</td>
<td>97.14</td>
</tr>
<tr>
<td>Joynagar</td>
<td>11</td>
<td>38</td>
<td>1438</td>
<td>97.43</td>
</tr>
<tr>
<td>Jugikhali</td>
<td>13</td>
<td>17</td>
<td>867</td>
<td>98.08</td>
</tr>
<tr>
<td>Kaila</td>
<td>5</td>
<td>16</td>
<td>740</td>
<td>97.88</td>
</tr>
<tr>
<td>Keragachhi</td>
<td>12</td>
<td>180</td>
<td>1478</td>
<td>89.14</td>
</tr>
<tr>
<td>Keralkata</td>
<td>20</td>
<td>144</td>
<td>1625</td>
<td>91.86</td>
</tr>
<tr>
<td>Kushadanga</td>
<td>15</td>
<td>16</td>
<td>1053</td>
<td>98.50</td>
</tr>
<tr>
<td>Nangaljhara</td>
<td>8</td>
<td>20</td>
<td>622</td>
<td>96.88</td>
</tr>
<tr>
<td>Sonabaria</td>
<td>8</td>
<td>100</td>
<td>1486</td>
<td>93.69</td>
</tr>
</tbody>
</table>

**Upazila summary:**

<table>
<thead>
<tr>
<th># of Village</th>
<th>Total TW</th>
<th>Arsenic Safe TW</th>
<th>Arsenic Conta. TW</th>
<th>% of TW Conta.</th>
</tr>
</thead>
<tbody>
<tr>
<td>136</td>
<td>17003</td>
<td>889</td>
<td>16114</td>
<td>94.77</td>
</tr>
</tbody>
</table>

Data from Bangladesh Water Supply Program Project

% Drinking Water Wells Contaminated with Arsenic (> 50 ppb)
ARSENIC CONTAMINATION

Number of patients soars for want of safe water

JASIM UDDIN KHAN

The number of severe arsenic contaminated patients in three times higher than the previous estimation done around two years ago, says a joint study of the government and IICA.

The study shows the number of arsenic poisoned patients is increasing alarmingly due to want of safe water sources in affected areas.

The study conducted under the project titled "Sustainable Arsenic Mitigation under Integrated Local Government System (SAM-ILGS)" also finds many unidentified patients die in last five years without proper treatment.

"The actual number of patients in the country could be even more than triple than that was identified previously if the contaminated areas are surveyed again," Kasumaki Kawahara, project manager, said.

The recent government arsenic project titled Bangladesh Arsenic Mitigation and Water Supply Project (RAMWSP) started in January 1998 and continued until June 2000.

Kawahara said they found 799 patients in Chowgacha upazila in Jessore while the previous RAMWSP found only 275 patients there.

"The main reason of increasing number of patients that previously the patients were identified by the field workers under RAMWSP whereas the patients have been identified under the new (SAM-ILGS) project by health assistants and confirmed by doctors," Kawahara added.

He said RAMWSP identified around 38,000 arsenic patients in 268 upazilas across the country. But if the areas are surveyed again and doctors confirm the patients, the number would cross even 1 lakh.

He emphasised initiating a fresh survey on the most vulnerable areas in Cumilla, Chandpur, Chapainawabganj and Faridpur.

According to the previous project, 4,036 patients were identified.

See page 15 col. 3
Arsenicosis Patient - Cambodia

Photo by T. Mahin
Variation of Arsenic Over Time
(Charts from British Geological Survey)
Kanchan Arsenic Filter
**Kanchan Arsenic Filter Performance***

*based on 1000+ filters in use for 1 year across Nepal

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Typical values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic</td>
<td>85-90% reduction</td>
</tr>
<tr>
<td>Iron</td>
<td>90-95% reduction</td>
</tr>
<tr>
<td>Phosphate</td>
<td>80-85% reduction</td>
</tr>
<tr>
<td>Turbidity</td>
<td>80-95% reduction</td>
</tr>
<tr>
<td>Total coliforms</td>
<td>85-99% reduction</td>
</tr>
<tr>
<td>pH</td>
<td>0.35-0.40 increase</td>
</tr>
</tbody>
</table>

Recommendation:  
Arsenic $\leq 0.5$ mg/L (500 ppb)  
Phosphates as PO4 $\leq 5.0$ mg/L  
pH $\leq 7.5$

Reference:  
Kanchan Arsenic Filter

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

• Arsenic may stay in the diffuser box (i.e. adsorbed to the surface of the rusted nails in the box), or the arsenic-loaded iron particles can be flushed down and trapped on top of fine sand

Arsenic (As) particles are effectively adsorbed on the rusted iron nails surface.
Selecting Filter Locations for CAWST/MIT/LEDARS Pilot Study

- Reviewed published data on arsenic levels in Bangladesh.
- Met and reviewed data with JICA staff in Bangladesh who were very helpful.
- Met with Asia Arsenic Network staff and discussed data sources.
- Met with DPHE (Department of Public Health Engineering) officials and discussed existing data.
- Talked with UNICEF about the worst contaminated areas in SW Bangladesh.
- Conducted preliminary field testing.
Asia Arsenic Network Lab
Jessore, Bangladesh

Photos by T. Mahin
Bangladesh Pilot Study
Performance of Kanchan Arsenic Filter S4B (plastic filter)

![Graph showing arsenic concentration over time]

- **Raw Water**
- **Treated Water**

**Bangladesh Drinking Water Standard**

Sampling Dates:
- March 9, 2007
- April 2, 2007
- September 15, 2007
- September 17, 2007
- December 15, 2007

{Graph details and data not transcribed due to image format limitations.
Bangladesh Pilot Study
Performance of Kanchan Arsenic Filter S3C (concrete filter)

Sampling Dates
- March 17, 2007
- March 25, 2007
- April 2, 2007
- Sept. 15, 2007
- Sept. 17, 2007
- Dec. 15, 2007

Arsenic Concentration (ppb)
- Bangladesh Drinking Water Standard

- Raw Well Water
- Treated Water
3 Parameters That Impact Arsenic Removal & Vary Tubewell by Tubewell

- **Phosphate** levels of in raw water. Bangladesh groundwater has relatively high phosphate levels. Higher phosphates reduce arsenic % removals.

- **pH** above 7.5 can reduce arsenic % removal by reducing positive charge of iron. High pH significantly impacted performance of 1 of 8 filters during pilot study.

- Higher naturally occurring **iron** levels increase arsenic % removals.
Impact of Phosphates on Arsenic Removal by Adsorption Systems

• Numerous studies have shown that phosphates can have a significant impact on the % arsenic removed by iron-based treatment systems.
• Because phosphates have similar chemical structure to arsenate (As$^{+5}$) they compete with arsenic for adsorption sites on iron oxides.
• For the same sample a phosphate result of 3 mg/L PO$_4$ = approximately 1 mg/L reported as P or PO$_4$-P.
Origin of Phosphates in Ground Water

• The likely sources of phosphates are decomposition of organic matter and weathering of minerals.

• Similar to arsenic in Bangladesh, phosphates appear to be concentrated in high iron (hydr)oxides (often as coating on sediments) and are released naturally by the dissolution of iron (hydr)oxides initiated by reducing (low dissolved oxygen) conditions.

• Fertilizers can potentially also contribute phosphates at shallower groundwater depths but in Bangladesh there often is clay layer near the surface minimizing such impacts from the surface.
Bangladesh Phosphate Results (DPHE/BGS)

- 0.3 mg/L P (median) for 3,530 samples
- But when As > 50 ppb, P averaged 1.5 mg/L (median - 1 mg/L)
In High Arsenic Areas of Bangladesh Phosphates Are Often Elevated Though Levels Can Vary Significantly

From McArthur et al. WATER RESOURCES RESEARCH (JANUARY 2001)

From “Targeting safe aquifers in regions with arsenic-rich groundwater in Bangladesh Case study in Matlab Upazill”a - Jonsson and Lundell (2004) Swedish University of
Ratio of Phosphates to Iron Vary by Individual Wells in Bangladesh Making Some Wells More Difficult to Treat Than Others

For **Well # 1** and **Well # 2** iron levels are very similar but **phosphates differ by a factor of 10**

Adapted From: Targeting safe aquifers in regions with arsenic-rich groundwater in Bangladesh Case study in Matlab Upazila - Jonsson and Lundell (2004) Swedish
Phosphate Levels Vary Widely Even Within Specific Areas

Adapted from British Geological Survey/DPHE 2000
With Increasing Iron, Phosphates (P) & Arsenic Removal Increases


Adapted from *O.X. Leupin, S.J. Hug / Water Research 39 (2005)*
Variation of Phosphates By Depth and by Month
(Charts from British Geological Survey – Bangladesh data)

**Faridpur phosphate**

Note - phosphate levels at 40 meters greater than phosphates at 20 m
**Impact of High Phosphates on As Removal in 2 Sets of Wells with Similar Iron levels (sand filter no nails)**

<table>
<thead>
<tr>
<th>Arsenic (As) In well ug/L</th>
<th>As - filtered water</th>
<th>% As removed</th>
<th>Natural Iron in well ppm (no nails)</th>
<th>Phosphates (as PO₄-P) mg/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vietnam (high naturally occurring iron)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>223</td>
<td>21</td>
<td>91%</td>
<td>11</td>
<td>0.05</td>
</tr>
<tr>
<td>137</td>
<td>49</td>
<td>64%</td>
<td>11</td>
<td>2.8</td>
</tr>
<tr>
<td>70</td>
<td>9</td>
<td>87%</td>
<td>7</td>
<td>0.2</td>
</tr>
<tr>
<td>55</td>
<td>44</td>
<td>20%</td>
<td>6</td>
<td>3.7</td>
</tr>
</tbody>
</table>

**Solution – Use 6 kg Nails to Increase Fe Levels & to Compensate for PO₄**

Bangladesh

<table>
<thead>
<tr>
<th>Arsenic (As) In well ug/L</th>
<th>As - filtered water</th>
<th>% As removed</th>
<th>8 + iron from nails</th>
</tr>
</thead>
<tbody>
<tr>
<td>171</td>
<td>25</td>
<td>85% with nails</td>
<td>2.3</td>
</tr>
</tbody>
</table>

Raw Data from: Berg et al. “Arsenic Removal from Groundwater by Household Sand Filters – Comparative Field Study, Model Calculations, and Health Benefits”– *E S & T*
The Impact of Phosphates on % Removal of Arsenic by Sand Filters

Comparison of Phosphates vs. Arsenic in One Area of Bangladesh

**High Arsenic Area of Cambodia (Kandal Province)**

Generally has high Phosphate (PO$_4$-P) levels & moderate Iron (Fe) levels

<table>
<thead>
<tr>
<th>PO$_4$-P (mg/L)*</th>
<th>As (ug/L)*</th>
<th>Fe (mg/L)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average - 0.66</td>
<td>Average – 233</td>
<td>Average – 2.8</td>
</tr>
<tr>
<td>Range:&lt;0.2–3.14</td>
<td>Range:1 -1340</td>
<td>Range&lt;0.05-16</td>
</tr>
</tbody>
</table>

* - Data from Swiss Institute of Aquatic Science and Technology, Eawag, as published in Environ. Sci. Technol 2007 41
Summary - Impact of Phosphates

KEY POINTS

• Elevated phosphate levels decrease arsenic removal efficiency.

• In the pilot study this was compensated for by increasing the amount of nails from 5 to 6 kg. Of the wells tested in the pilot study none had performance problems caused by phosphates.
Impact of pH on Arsenic Removal
Example of Impact of Raw Water pH on % As Removal, Impact Increases when Phosphates Very High

If phosphates are high then tubewells with pH > 7.5 have reduced arsenic removal efficiency

From Zeng et al. 2008 in E, S & T
High pH Reduces Charge of Iron
Reducing % As Removal
(critical pH varies by type/form of iron)

Fig. 1. (a) Zeta potential of GFH as a function of pH

Example of pH vs. Depth
Bangladesh

From: Bhattacharya et al.
pH Data from 207 Wells in Cambodia

Fig. 3. Bivariate plots of arsenic and selected parameters measured in groundwater samples of the upper Mekong Delta, Cambodia and Vietnam. Open circles (○) are samples from Cambodia (n = 207), black dots (●) from southern Vietnam (n = 112). a) redox potential–arsenic, b) pH–arsenic, c) ammonium–arsenic, d) dissolved organic carbon–arsenic.

Data from Cambodia is non-filled in circles “ ○ ” (207 samples). From “Magnitude of arsenic pollution in the Mekong and Red River Deltas — Cambodia and Vietnam” by Berg et al. in Science of the Total Environment 2007.
Example of pHs in High Arsenic Area - Nepal

Table 5  Results from water analyses, Nawalparasi Nepal

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>As conc. (ppm)</th>
<th>Fe conc. (ppm)</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>NP-1</td>
<td>0.35</td>
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ND not detected

In Some Parts of the World, High Arsenic is the Result of High pH GW That Causes Desorption of As From Iron Oxides

From: Gosh et al., Science of the Total Environment 2006
Impact of pH

Key Points

• High pH of tubewell water decreases percent removal of arsenic.

• While 1 well in Bangladesh had reduced arsenic removal (approx. 60% removal) due to high pH, the great majority of wells in Bangladesh (and it appears Cambodia) are near neutral and for these wells pH shouldn’t be a problem.

• In countries with arid high pH areas (Argentina, Inner Mongolia, etc.) pilot testing would need to be performed to evaluate significance of high pH.
Impact of Iron

Photo by T. Mahin
Bangladesh
Iron Varies Greatly in High Arsenic Wells

From McArthur et al. WATER RESOURCES RESEARCH (JANUARY 2001)
Impact of Tubewell Iron Levels on Arsenic Treatment Efficiency

- Iron levels in tubewells vary from arsenic levels.
- Naturally occurring high iron levels increase % removals of arsenic and can help compensate for high phosphate levels.
- Even with high iron levels in raw water (tubewell) KAF effectively removes iron.