**Recommendations**

Promote and regulate commercial tubewell testing for arsenic  
Launch national campaign to update households on risks of arsenic exposure  
Encourage households to have their tubewell tested if status is in doubt  
Disseminate arsenic-safe depth at the village level (past and new testing)  
Encourage drillers and households to target low-arsenic aquifers
Recommendations
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Encourage drillers and households to target low-arsenic aquifers
Recommendations based on 12 years of arsenic mitigation in Araihazar, Bangladesh

Alexander van Geen (avangeen@ldeo.columbia.edu) and Kazi Matin Ahmed (kazimatin@yahoo.com)

Benjamin Bostick
Brian Mailloux
Peter Schlosser
Yan Zheng
Martin Stute

Joseph Graziano
Habibul Ahsan
Mary Gamble
Yu Chen
Maria Argos
Over 100 million across South/East Asia drink water with >10 ug/L As (WHO guideline)
Bangladesh most affected
Regional variability within Bangladesh

BAMWSP/NAMIC
Araihazar upazilla: Columbia/Dhaka University study area since 2000

Groundwater arsenic (ug/L)
- >50
- 10-50 Bangladesh standard
- <10 WHO guideline
Main public health results from cohort study in Araihazar

Arsenic exposure from drinking water, and all-cause and chronic-disease mortalities in Bangladesh (HEALS): a prospective cohort study

400 deaths within cohort of 12,000 over ~8 years
All-cause death almost twice as high when drinking >150 ug/L As compared to <10 ug/L (WHO guideline)

Also dose-response relationships for: skin lesions
mental development of children
Groundwater is the cause of poisoning but also the main solution

Epidemiology

Ensuring Safe Drinking Water in Bangladesh


Excessive levels of arsenic in drinking water is a vast health problem in Southeast Asia. Several viable approaches to mitigation could drastically reduce arsenic exposure, but they all require periodic testing.

Ahmed et al., Science, 2006
Results from testing of 10,027 wells by 10 village health workers in 4 months

10 village health workers and 2 supervisors
Md. Zakir Hossein  Ershad Bin Ahmed Shumon
Each VHW tests 12 wells between 8 AM and 3 PM

New kit first deployed in Bangladesh by Christine George/Yan Zheng, UNICEF (US$85/300 tests)
Data entry in the field directly on handheld Garmin GPS Map76Cx (US$164 ea.)
Google Earth for quality control
Durable placards with result attached to handpumps

DPHE agreed to 3 colors/2 statements

10% near limits misclassified
Results for 10,027 of ~30,000 tubewells in upazilla
27% perceived as “safe”
16% perceived as “unsafe”
57% status unknown

Tubewell status according to households (n=10,027)
Tubewell usage according to households (n=10,027)

- 57% status unknown
- 87% consumed
- 27% perceived as “safe”
- 98% consumed
- 16% perceived as “unsafe”
- 46% consumed
Actual arsenic concentration relative to perceived status (n=10,027)

- Arsenic (ug/L)
  - ≤10
  - 10-50
  - >50

- 27% perceived as “safe”
- 46% perceived as “unsafe”
- 57% status unknown
- 98% consumed
- 87% consumed
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Actual arsenic concentration relative to perceived status (n=10,027)

- 27% perceived as “safe”
  - 98% consumed
- 16% perceived as “unsafe”
  - 46% consumed
- 57% status unknown
  - 87% consumed
Close-up of 2 villages
Most high-arsenic wells within walking distance of low-arsenic well

Edbardi village
193/357 wells
54% >50 ug/L
Two main obstacles to lowering of exposure

Edbardi village
176/357 wells
49% untested

53/105
50% of households knowingly drink from unsafe well
Arsenic-safe depth within reach of local drillers in Edbardi village

“Hand-flapper”
1 day

“Donkey pump”
~5 days
Arsenic-safe depth beyond reach of local drillers in Dakshinpara village
Cost of tubewell testing relative to installation

Total budget for testing 30,000 wells (5% twice for quality-control)
2 supervisors and 10 village-health workers for 12 months
BTK 5,400,000 (US$66,000)

BTK180/test (US$2.20/test) vs. BTK8,000-24,000 (US$100-300) for a 100-300 ft tubewell

US$22 million for testing 10 million tubewells vs. >US$1 billion spent by households
Findings

Status of 57% of wells unknown in Araihaazar because of installations of last 10 years, probably an even higher portion in other As-affected areas.

65% of households aware of high arsenic in their well still drinking and cook from it, in many case even if a low-arsenic well is within walking distance.

Proportion of tubewells meeting the Bangladesh standard for arsenic installed since the 2003 blanket survey has increased only from 50 to 55%.

Over 300 deep wells installed in 21 villages that need them, 9 villages that don’t, but none in 17 villages that do.

Recently introduced ITS Arsenic Econo-Quick kit adequately establishes well status relative to WHO guideline (10 ug/L) and Bangladesh standard (50 ug/L).

Village workers can test 12 wells/day at a total cost of BTK180/well that covers the kit, hand-held GPS for data entry, placard, and salaries (incl. supervisors).
Recommendations
Promote and regulate commercial tubewell testing for arsenic
Launch national campaign to update households on risks of arsenic exposure
Encourage households to have their tubewell tested if status is in doubt
Disseminate arsenic-safe depth at the village level (past and new testing)
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Extras
Where does the arsenic come from?

Fe(III) oxides

Dissolution of iron oxides driven by organic matter degradation

Fe(II) oxides

Crustal As ~ 1 mg/kg

Fendorf et al. Science 2010
What if there is no low-arsenic well within walking distance?
“Only” 4 failures out of 50 community wells over 10 years

van Geen et al., 2007
Depth and age of tubewells

![Graph showing well installation year versus well depth with different colored dots representing depths and installation years.]

- Red dots: >50 ft
- Green dots: 10-50 ft
- Cyan dots: <10 ft
- Yellow dots: Unknown

Well installation years are marked from 1970 to 2010.
Performance of field kit when deployed by village health workers

N=189

<table>
<thead>
<tr>
<th></th>
<th>kit underestimate</th>
<th>kit overestimate</th>
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</thead>
<tbody>
<tr>
<td>Relative to 10 ug/L</td>
<td>9%</td>
<td>0.5%</td>
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<tr>
<td>Relative to 50 ug/L</td>
<td>3%</td>
<td>4%</td>
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George et al. *Env. Sci. Technol.* under revision
Comparison with laboratory for wells still tagged after 10 years
### Accounting

**Monthly budget - Arsenic Testing Project, Araihazar**

**Expected duration**: 12 months

<table>
<thead>
<tr>
<th>Assumptions:</th>
<th>Compensation</th>
<th>5% of wells re-tested by manager and supervisor</th>
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</thead>
<tbody>
<tr>
<td>No. wells tested by each VHW (12 per day and 20 days per month)</td>
<td>BTK 20/test</td>
<td>BTK 40/test</td>
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<tr>
<td></td>
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<td>@82 BTK/USD</td>
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**Personnel**

<table>
<thead>
<tr>
<th>Personnel</th>
<th>No.</th>
<th>Fixed</th>
<th>Compensation</th>
<th>Travel allowance</th>
<th>Total/month</th>
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</thead>
<tbody>
<tr>
<td>local PI, manager, and supervisor</td>
<td>2</td>
<td>BDT 70,000</td>
<td>BDT 4,800</td>
<td>BDT 10,000</td>
<td>BDT 84,800</td>
</tr>
<tr>
<td>Village health workers</td>
<td>10</td>
<td>BDT 4,100</td>
<td>BDT 4,800</td>
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<td>BDT 89,000</td>
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**Supplies**

- Metal placards + SS wire @ BTK75 ea.
- Miscellaneous (notebooks, pliers, markers, tissue, etc.)

**Supplies**

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**Monthly**

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<tbody>
<tr>
<td>12 months/28,800 tests</td>
<td>BDT 4,425,600</td>
<td>USD 53,971</td>
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<tr>
<td>Provided separately:</td>
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<tr>
<td>12 Handheld GPS units @USD164 ea.</td>
<td>USD 1,968</td>
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<tr>
<td>Econo-Quick kits @USD85/300 tests</td>
<td>USD 8,160</td>
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**Total**

|                                                      | USD 64,099  | (or USD 2.23/test) |

2,400 x 12 mo. = 28,800 in 1 yr (BAMWSP ~15,000 for Araihazar in 2003)

Cost to households of re-installing 5 million wells ~ UD$500 million
Cost of testing these wells ~$10 million

Like drilling, testing could be for-profit
Key role for gov’t/NGOs/universities is training and (re-)certification program
Actual arsenic concentration relative to perceived status (n=10,027)

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