Declining exposure of Health Effects of Arsenic Longitudinal Study (HEALS) cohort over 18 years: Causes and consequences

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Columbia University
Declining exposure of Health Effects of Arsenic Longitudinal Study (HEALS) cohort over 18 years: Causes and consequences

Causes: primarily well switching and well drilling

Consequences: large decline in exposure indicated by urinary arsenic

national policy?
HEALS baseline survey 2000-01

Habib Ahsan

Joe Graziano

Kazi Matin Ahmed
HEALS baseline survey 2000-01
4,331 out of 6,000 wells total
HEALS 6th follow-up 2017-18
HEALS baseline survey 2000-01
4,331 out of 6,000 wells total
HEALS 6th follow-up 2017-18

4,390 out of >11,000 total wells
recruited 2000-2002
11,746 participants
4,331 wells

Well-water As from 2000-01 to 2017-18

as of August 31, 2018
9,138 participants
4,390 wells
Well-water As from 2000-01 to 2017-18

recruited 2000-2002
11,746 participants
4,331 wells

as of August 31, 2018
9,138 participants
4,390 wells
Changes in well-water As from 2000-01 to 2017-18

Urine from 1098 HEALS participants (10% of cohort) analyzed in Joe Graziano’s lab
Changes in well-water As from 2000-01 to 2017-18

Urine from 1098 HEALS participants (10% of cohort) analyzed in Joe Graziano’s lab
Forms of arsenic mitigation (short and longer-term)
HEALS 6th follow-up 2017-18: shallow wells (<150 ft)

4,474 participants (48%)
HEALS 6th follow-up 2017-18: intermediate wells (>150 ft and <300 ft)
3,726 participants (41%)
HEALS 6th follow-up 2017-18: deep wells (>300 ft)

938 participants (10%)
Installations years reported in 2017-18

Shallow wells (<150 ft)

Intermediate wells (150-300 ft)

Deep wells (>300 ft)

48% of participants
41% of participants
10% of participants
Are findings relevant beyond the HEALS area?
Entire Araihazar upazila
Well depths from 2013 blanket survey

- Shallow wells (10-45 m)
- Intermediate wells (45-90 m)
- Deep wells (90-300 m)
HEALS area vs. all of Bangladesh

<table>
<thead>
<tr>
<th>Year</th>
<th>&gt;10 ug/L</th>
<th>&gt;50 ug/L</th>
</tr>
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<tr>
<td>2000</td>
<td>57M</td>
<td>35M</td>
</tr>
<tr>
<td>2009</td>
<td>52M</td>
<td>22M</td>
</tr>
<tr>
<td>2013</td>
<td>40M</td>
<td>20M</td>
</tr>
<tr>
<td>2018</td>
<td></td>
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HEALS area vs. all of Bangladesh

Bangladesh

HEALS area

-43%

-74%
Major obstacle is lack of testing since 2000-05 BAMWSP

Bangladesh

- 2000: >50% >10%, 11-50%, ≤10%
- 2009: >50% >10%, 11-50%, ≤10%
- 2013: >50% >10%, 11-50%, ≤10%
- 2018: -43%

HEALS area

- 2000: >50% >10%, 11-50%, ≤10%
- 2009: >50% >10%, 11-50%, ≤10%
- 2013: >50% >10%, 11-50%, ≤10%
- 2018: -74%

Araihazar

- “safe”
- “unsafe”
- unknown
## Impact and cost of mitigation: testing and switching (short term)

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<td>$1 per exposure reduced</td>
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27,500 x 0.60* x 8 = 132,000

unsafe wells switching users per well exposure reduced

48,800 x $2.50 = $122,000

wells tested cost per test+placard total cost of testing

*Madajewicz et al. *J. Dev. Econ.* 2007
Chen et al. *Env. Health Perspect.* 2007
Are HEALS findings relevant elsewhere?
Outside HEALS but within Araihaazar
Response survey after 2003 BAMWSP testing

survey of 4,100 households in 76 villages in 2005 more switched by 2008, and none had switched back

Balasubramanya et al.
Are Araihazar findings relevant elsewhere?
Araihazar vs. neighboring Sonargaon
Selection of households (25%) who purchased a $0.60 test

Alessandro Tarozzi, Universitat Pompeu Fabra, Barcelona
Ricardo Maertens, now a post-doc at Harvard

Also: George et al. *Env. Health* 2012  53% switching across 20 villages in Singair upazila (with placards, community meetings)
## Impact and cost of mitigation: private intermediate wells (longer term)

3,726 HEALS participants (41%)

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<td>8,450 intermediate wells installed (7,610 safe)</td>
<td>67,600</td>
<td>90%</td>
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<td>1,690,000</td>
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8,450 x 0.90 x 8 = 64,800  
intermediate wells  
safe  
users per well  
exposure reduced

8,450 x $200 = $1,690,000  
Intermediate wells  
per intermediate well  
total cost of intermediate wells

$28 per exposure reduced
## Impact and cost of mitigation: government deep wells

938 HEALS participants (10%)

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<td>916 deep wells installed (907 safe)</td>
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<td>800</td>
<td>733,000</td>
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\[
\text{907 safe deep wells} \times \text{6,400 unsafe wells within 100 m switching users per well} \times 8 = 5,120 \text{ exposure reduced}
\]

\[
\text{916 deep wells} \times \text{$800 per deep well} = 733,000 \text{ total cost of deep wells}
\]

\[\text{\$143 per exposure reduced}\]

# Impact and cost of mitigation: piped-water supply system

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<td>Piped Water Supply</td>
<td>312 connections installed (all safe)</td>
<td>2,180</td>
<td>100%</td>
<td>2,180</td>
<td>250,000</td>
<td>250,000</td>
<td>300 *</td>
<td>93,600</td>
<td>158</td>
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*10 years @ US$2.50/month

\[ 312 \times 7 = 2180 \]  
312 x 7 = 2180  
users per tap exposure reduced

\[ 250,000 + 312 \times 2.50 \times 120 = 343,000 \]  
$250,000 + 312 x $2.50 x 120 = $343,000  
per system taps per month months total cost per system

$158 per exposure reduced
Where is most of the new government funding going?

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*a10 years @ US$2.50/month

Where is the greatest potential for improvements?
# Optimized truly public deep wells

Goal similar to Malgosia Madajewicz and Anna Tompsett’s RCT

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- **907 safe deep wells optimized**
  - 16,500 unsafe wells within 100 m
  - switching
  - users per well
  - exposure reduced = $79,200

- **907 safe deep wells actual**
  - 6,400 unsafe wells within 100 m
  - switching
  - users per well
  - exposure reduced = $5,120

- **916 deep wells**
  - $800 per deep well
  - total cost of deep wells = $733,000

$9 per exposure reduced
Proposed RCT to quantify short and medium-term impacts

Prabhat Barnwal, Michigan State University
NSF Decision, Risk and Management Sciences

140 villages

Phase 1: Group-formation

C
Pure control – No arsenic testing (20 villages)

A
Control: arsenic testing (60 villages)

G
Treatment: arsenic testing after group-formation (60 villages)

Phase 2: Deep well demonstration

ADY
Well installation demo for one randomly selected household (30 villages)

APY
Placard (30 villages)

APN
No Placard (30 villages)

GTY
Well installation demo for network central household (30 villages)

GPN
No Placard (30 villages)

ADN
No Well installation demo (30 villages)
Well sharing coupons piloted in Bihar

Prabhat Barnwal, Michigan State University
Chander Kumar Singh, TERI School of Advanced Studies
RCT across 5 upazilas
Will any of these findings be taken into account?
Causes: primarily well switching and well drilling
private initiatives more than government
free tests, placards

Consequences: large decline in exposure indicated by urinary arsenic
maybe a reduction in some diseases, e.g. CVD
could convey an optimistic message leading to action
national policy?
risk-sharing groups, demonstration wells
impact score for truly public deep wells
extras
Evolution of urinary arsenic from 2000-01 to 2017-18
Charlie Harvey and Britt Huhmann, MIT
Urinary As vs. Water As in 2000-01

Charlie Harvey and Britt Huhmann, MIT

Graph 1:
- Urinary Arsenic (µg/L) vs. Primary Household Well Arsenic (µg/L)
- R² = 0.247
- n = 2811
- slope = 0.64
- intercept = 73

Graph 2:
- Urinary Arsenic (µg/L) vs. Primary Household Well Arsenic (µg/L)
- R² = 0.247
- n = 2811
- slope = 0.64
- intercept = 73
(a) Shallow wells

(b) Intermediate wells

(c) Deep wells
## Impact and cost of mitigation: testing and switching

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<td>$1.10 per exposure reduced</td>
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\[
27,500 \times 0.30 \times 8 = 66,000
\]

Unsafe wells switching users per well exposure reduced

\[
48,800 \times \$1.50 = \$73,200
\]

Wells tested cost per test total cost of testing