The Case for Universal Screening of Private Well Water Quality in the U.S.: Evidence from Arsenic

Cost-effectiveness Analysis of Lead Poisoning Screening Strategies Following the 1997 Guidelines of the Centers for Disease Control and Prevention


To compare 4 screening strategies:

1. Universal screening of venous blood lead (BPb) levels
2. Universal screening of capillary BPb levels
3. Targeted screening of venous BPb levels for those at risk
4. Targeted screening of capillary BPb levels for those at risk

- In high-prevalence populations, Universal venous screening detects all cases of lead poisoning and is the most cost-effective, at $490 per case detected.

- In populations with lower prevalence, the cost per case detected using targeted screening ($556) is less than that of universal screening ($729).

Table 2. Distribution of Elevated BPb Level Used in the Model

<table>
<thead>
<tr>
<th>Prevalence</th>
<th>≥0.48 μmol/L (≥10 μg/dL)†</th>
<th>0.48 to &lt;0.72 μmol/L (10 to &lt;15 μg/dL)</th>
<th>0.72 to &lt;0.97 μmol/L (15 to &lt;20 μg/dL)</th>
<th>0.97 to &lt;2.17 μmol/L (20 to &lt;45 μg/dL)</th>
<th>2.17 to &lt;3.38 μmol/L (45 to &lt;70 μg/dL)</th>
<th>3.38 μmol/L (≥70 μg/dL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>5.9</td>
<td>4.0</td>
<td>1.2</td>
<td>0.7</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Medium</td>
<td>12.0</td>
<td>8.5</td>
<td>2.3</td>
<td>0.9</td>
<td>0.3</td>
<td>...</td>
</tr>
<tr>
<td>High</td>
<td>44.1</td>
<td>27.9</td>
<td>14.7</td>
<td>1.0</td>
<td>0.4</td>
<td>0.1</td>
</tr>
</tbody>
</table>

*BPb indicates blood lead.
†Summarizes the total prevalence of elevated BPb for low, medium, and high groups.
American Academy of Pediatrics issued a policy statement in 2009 and reaffirmed it in 2013, recommending *annual testing*
Eight inorganic contaminants exceed human health benchmarks at >1%: Sr 7.3% (n=488) HBSL, As 6.8% (n=1,774) MCL, Mn 5.2% (n=2,159) HBSL, Nitrate 4.4% (n=2,132) MCL, Rn 4.4% (n=1,958) Prop. MCL, U, B, F 1 – 2%

Organic contaminants occur much less frequently: Dieldrin, 0.43% (n=2,115), the most.
• Arsenic point data base
  Public water supply:  \( n = 2,262 \)
  Other potable well water: \( n = 16,602 \)

• Arsenic occurrence

\[
\begin{array}{|c|c|}
\hline
[As] (\mu g/L) & \% \text{wells} \\
\hline
>1 & 36 \\
>5 & 14 \\
>10 & 8 \\
>50 & 1 \\
\hline
\end{array}
\]
The Chemical Quality of Self-Supplied Domestic Well Water in the United States

Focazio et al. 2006

- Inorganic contaminants
  Sr 10.6% (n=7,580) MCL
  As 8.4% (n=3,465) MCL
  Mn
  Nitrate 9.0% (n=4,820) Prop. MCL
  U 3.7% (n=2,390) MCL
  F 0.8% (n=15,495) MCL

Figure 4. Detections and MCL exceedances for all analyses of VOCs, pesticides, uranium, and arsenic.
Variable Prevalence of Arsenic in Private Well Water in 2 by 2 mile grids of 
Central Maine (n=23,500) 
northern New Jersey (n=35,500)

\[\text{%> 10 \, \mu g/L \text{ As (US MCL)}}\]
\[0 \text{ – 68.8\%, mean 23.6\% } \pm 3.5\%\]

\[\text{%> 5 \, \mu g/L \text{ As (NJ MCL)}}\]
\[0 \text{ – 72.5\%, mean 21.6 } \pm 3.2\%\]
Correlation Between Prevalence of Arsenic and Median As Concentration in 2x2 mile grids (n=121) in New Jersey

Equal Area Grid Analysis Generates Representative Aquifer Properties
Belitz et al WRR 2010
What we know

- Despite the uneven and incomplete sampling coverage of private wells in the US, arsenic is most likely to occur in about 10% of groundwater used for domestic purposes nationwide.
- In a given community, there is a great deal of variability in arsenic occurrence (prevalence) rate that is correlated with median As level.
- An ongoing USGS assessment suggests that high private well water As concentrations are spatially clustered throughout the conterminous US.
Why Universal Testing Requirement?

- Voluntary testing rates for arsenic are about 50%, resulting in persistent exposure in >50% of at risk households.
- Voluntary testing rates will never reach 100% due to socioeconomic, behavioral (psychological) and situational factors.
- Increasing voluntary testing rates from 50% to 100% is a lot harder than doing so from 0% to 50%.
- Local testing requirement works well, for example the New Jersey Private Well Testing Act (PWTA).
- Testing requirement re-directs publically funded community engagement efforts to *actual* exposure reduction: avoidance or treatment for arsenic among the vulnerable groups.
Help is needed for households who have tested and found As

Dissemination of well water arsenic results to homeowners in Central Maine: Influences on mitigation behavior and continued risks for exposure

Flanagan et al 2015a

<table>
<thead>
<tr>
<th>Action</th>
<th>As measured by Columbia</th>
<th>Yang et al ES&amp;T 2009, 2012</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10–50 μg/L   (N = 201)</td>
<td>N (%)</td>
</tr>
<tr>
<td></td>
<td>51–100 μg/L (N = 39)</td>
<td>n (%)</td>
</tr>
<tr>
<td></td>
<td>&gt;100 μg/L     (N = 16)</td>
<td>n (%)</td>
</tr>
<tr>
<td>Installed POE system</td>
<td>11 (5.5%)</td>
<td>7 (17.9%)</td>
</tr>
<tr>
<td>Installed POU system</td>
<td>65 (32.3%)</td>
<td>20 (51.3%)</td>
</tr>
<tr>
<td>Switched to bottled</td>
<td>63 (31.3%)</td>
<td>7 (17.9%)</td>
</tr>
<tr>
<td>Other mitigation action</td>
<td>11 (5.5%)</td>
<td>3 (7.7%)</td>
</tr>
<tr>
<td>No action taken</td>
<td>63 (31.3%)</td>
<td>4 (10.3%)</td>
</tr>
</tbody>
</table>

Percentages add up to more than 100% because some respondents reported taking several actions, i.e. installing a system and switching to bottled water, in response to arsenic. N, n, number of samples.

**Good News:** Dose Dependent Protective Action

**Bad News:** Only 70% households act on testing results
Persistent Exposure When Testing Rate is 50%  

A community with 1000 private wells  

As prevalence: 20%  
Testing rate: 50%  

Exposed HHs: 200  
No longer exposed: 63  
Still exposed: 137  

69% of at risk HHs remain exposed at 50% testing rate  

Three exposure pathways  
- Unaware: 100 HHs  
- Tested but do nothing: 30 HHs  
- Tested, treating, treatment failing: 7 HHs  

Zheng & Ayotte 2015
Persistent Exposure Remains Even After Testing Rate Reaches 100%

A community with 1000 private wells

Four As prevalence rates: 1%, 10%, 20% and 50%

Assumptions:
30% tested but do nothing
10% treatment failure

37% of all at risk HHs remain exposed at 100% testing rate
Reason #1 Why Voluntary Testing Rate Will Never be 100%: Optimistic Bias
People believe they are less at risk compared to others

### Has treated water been tested by a lab?

<table>
<thead>
<tr>
<th></th>
<th>#</th>
<th>% of treating HHs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>163</td>
<td>40%</td>
</tr>
<tr>
<td>No</td>
<td>199</td>
<td>49%</td>
</tr>
<tr>
<td>Don’t know</td>
<td>31</td>
<td>8%</td>
</tr>
</tbody>
</table>

Flanagan et al
Stuffing Survey
Envelopes with $2
Reason #2 Why Voluntary Testing Rate Will Never be 100%:
Socioeconomic Vulnerability
Households with lower income and no bachelor’s degree testing and treating less

Arsenic in private well water part 3 of 3: Socioeconomic vulnerability to exposure in Maine and New Jersey (pre-PWTA households) Flanagan et al 2016c

$20,000 increase in HH income = 7% increase in probability of having tested

$25,000 increase in HH income = 4% increase in probability of having tested

Mean Prevalence: 23.6%
Mean Prevalence: 21.6%
Reason # 3 Why Voluntary Testing Rate Will Never be 100%:
– Free and Convenient Testing Gets a 47% Testing Rate

Sample bottles with free testing offer shipped to 255 HHs, a subset of 670 HHs randomly selected from 17 NJ towns for our surveys, selected based on:
1) Arsenic concentrations known from PWTA records to be > 4 μg/L (n=55)
2) Self-reported arsenic problems (n=23)
3) **Self-reported “never tested for arsenic”** (n=177)
Local Testing Requirement Works Well, but Slowly

Survey mailed to 1,943 HHs
670 HHs (37%) responded

- Without testing requirement, only 1 in 5 wells exceeding the As MCL is identified.
- With testing requirement, nearly all wells exceeding the As MCL are identified by household.
- Testing requirement reduces socio-economic disparities, benefits children.
Testing requirement re-directs publically funded community engagement efforts to *actual* exposure reduction

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**Table 4**

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<tbody>
<tr>
<td></td>
<td>10–50 µg/L (n = 63)</td>
</tr>
<tr>
<td>Not concerned about As</td>
<td>26</td>
</tr>
<tr>
<td>Treatment too expensive</td>
<td>20</td>
</tr>
<tr>
<td>Didn’t know what to do</td>
<td>6</td>
</tr>
<tr>
<td>Didn’t know who to contact</td>
<td>3</td>
</tr>
<tr>
<td>Other</td>
<td>18</td>
</tr>
</tbody>
</table>

*<sup>a</sup> „Neighbors in this area have lived to an old age without any problems.”*  

*<sup>b</sup> „The danger was overstated;” “testing stated water was ‘safe for consumption’. ”*  

- Household water treatment industry is not regulated
Twelve states require water to be tested for at least coliform bacteria when new private wells are constructed.

- Oregon requires water to be tested during a real estate transaction.
- Rhode Island and New Jersey require testing for both.

Only 5 states include arsenic:
- New Jersey PWTA
- Oregon Domestic Well Testing Act (DWTA)
- Minnesota, Wisconsin, and North Carolina for newly constructed private wells.

In 22 states (13 with no known state-wide regulation), local ordinances are stricter than state regulations.
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