New Jersey Township Ordinance for Arsenic Treatment Reduces Cancer Risk

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Private Wells in NJ

- **1,150,000** NJ residents drink private well water
- **~400,000** private wells
- 2002 - U.S. EPA established a drinking water standard of **10 ppb** for arsenic and a **MCLG of zero**
- 2006 - New Jersey **5 ppb**
- New Jersey Private Well Testing Act (**PWTA**) - Testing during real estate transactions - No treatment required
Hopewell Township, N.J.

- Located in Mercer County, New Jersey
- Population of ~ 17,000
- Has an ordinance requiring arsenic treatment
Arsenic Treatment System Types

Point of Use

Point of Entry (POET)

https://canyonstateac.com/blogs/what-is-a-reverse-osmosis-water-treatment-system
Arsenic Treatment

(Spayd, 2007)
Hopewell Township Requires:

- **Testing**
  - Homeowners: PWTA list during house sale
  - Renters/Landlords: Change in tenancy or
    - Annually: Total coliform
    - Tri-Annually: VOC, Lead, Arsenic, Gross Alpha, Cadmium

- Whole-house treatment system (Point of Entry) for any contaminants that exceed primary standards
- Post-installation test sent to health dept.
- Deed Amendment
- Maintenance Contract
Arsenic Treatment Systems in Hopewell Township, N.J.

Arsenic System POET Criteria

3. Must be redundant in design with dual tanks in series that utilizes Granular Ferric Adsorption media or other media as approved by NJDEP. Systems must contain all components as outlined by the NJDEP dual tank schematic found on the information circular available on the NJDEP web site.

http://www.state.nj.us/dep/pwta/Arsenic_Treatment.pdf

a. Sampling ports for raw, between tanks (middle), and finish water
b. Sediment pre-filter with replaceable cartridge to screen to 5-micron nominal
c. Capable of preventing media compacting resulting from fine sediments and constant gravity as well as eliminating the possibility of channeling. 
   Note: both tanks that hold the media must have an electronic backwash valve set to function no more than once every 20-30 days.
d. Vessels that house the media must be of industry standard type and sizing to permit future compatibility for new media technology adaptability
e. A water totalizer or meter on the finish water line to accurately provide treated water volume in gallons to be recorded at each time of maintenance testing.

4. The treatment system must remove all forms of arsenic, i.e. AS3 and AS5

5. Pre-treatment system must be employed for levels in excess of:
   a. iron above 0.3 mg/L
   b. manganese above 0.05 mg/L
   c. sulfur above 1.0 mg/L or smell detection
   d. hardness above 300 mg/L
   e. pH range 6.5 – 8.0
   f. silica less than 30 mg/L

6. Property owners are required to maintain a service agreement. The agreement must include:
   a. Water test samples, all of which have been taken from the middle sampling port or between the tanks.

http://tinyurl.com/HopewellWater
Specific Aims

• Determine the status and maintenance of arsenic treatment systems and their impact on arsenic removal efficacy.
  – What is the status of treatment systems in Hopewell Township?
  – Does maintenance schedule adherence affect arsenic removal efficacy?
  – Is treatment media breaking though and entering the home’s drinking water?

• Determine the arsenic exposure and risk reduction for homes with treatment systems.
  – What is the average yearly exposure to arsenic in homes with treatment systems?
  – What is the risk reduction achieved by these treatment systems? (Raw vs. treated)
  – What is the cancer risk for these individuals?
  – Is a dual tank arsenic treatment system protective of public health?
Methods: Identify Residences with As Treatment Systems

- Two hundred homes with arsenic treatment systems were identified in April 2014
- For 100 of these homes, the type of system and installer was also identified
Methods: Participant Recruitment

- Hopewell Township residents were contacted via a post-card mailing and a follow up phone call and email (if available)
- Compensation for participation was a free water test, estimated value $200
- 200 post cards were mailed
- 65 participants were recruited
- A visit to the participant’s home was scheduled at their convenience
Methods: Summary of Residential Inspection and Sample Collection

1. Survey and Discussion (20 mins)
2. Water Tests
   1. Water Quality Parameters
   2. Arsenic Speciation
   3. Water Sample Collection
3. Sediment Sample Collection
   1. Toilet Tanks
   2. Faucet Screens

Each home visit ranged from 1 – 3 hours.
Methods: *Residential Inspection and Sample Collection*

- Water samples were taken from the raw (untreated) valve, between tanks valve (if available) and kitchen tap and an additional water sample was taken if they had a reverse osmosis system.
- Water samples were sent to New Jersey Analytical Laboratory.

Spayd, 2007
Methods: Residential Inspection and Sample Collection

- An In-Situ 9500 low-flow groundwater sampling probe: measure water temperature, pH, redox potential (ORP), dissolved solids, and dissolved oxygen
- Rapid Colorimetric Field Test Strips: estimate hardness, chlorine, pH and alkalinity
- Arsenic speciation was performed using Metalsoft Arsenic Speciation Cartridges
Methods: *Residential Inspection and Sample Collection*

Sediment samples were taken from faucet screens and toilet tanks to determine if there was any breakthrough of the treatment media.
Results: Sampling Locations
# Results: Demographics

<table>
<thead>
<tr>
<th></th>
<th>Study Population</th>
<th>Proportion</th>
<th>Hopewell Township</th>
<th>Proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>48.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>46</td>
<td></td>
<td>44.4&lt;sup&gt;1&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>26</td>
<td>40.0%</td>
<td>8509&lt;sup&gt;1&lt;/sup&gt;</td>
<td>49.8%</td>
</tr>
<tr>
<td>Female</td>
<td>39</td>
<td>60.0%</td>
<td>8795&lt;sup&gt;1&lt;/sup&gt;</td>
<td>50.8%</td>
</tr>
<tr>
<td><strong>Education</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High School &amp; under</td>
<td>0</td>
<td>0.0%</td>
<td>5.3%</td>
<td></td>
</tr>
<tr>
<td>High School Degree</td>
<td>0</td>
<td>0.0%</td>
<td>12.1%</td>
<td></td>
</tr>
<tr>
<td>Some College</td>
<td>0</td>
<td>0.0%</td>
<td>12.8%</td>
<td></td>
</tr>
<tr>
<td>Associate’s Degree</td>
<td>2</td>
<td>3.1%</td>
<td>5.2%</td>
<td></td>
</tr>
<tr>
<td>Bachelor’s Degree</td>
<td>26</td>
<td>40.0%</td>
<td>28.8%</td>
<td></td>
</tr>
<tr>
<td>Graduate Degree</td>
<td>37</td>
<td>56.9%</td>
<td>36.4%</td>
<td></td>
</tr>
<tr>
<td><strong>Home Value</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>$586,888</td>
<td></td>
<td>$466,300&lt;sup&gt;2&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>$612,400</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Age of Youngest Child</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Homes with Children</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>50</td>
<td>76.9%</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Number of Children at home</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>1.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Number of Adults at Home</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>2.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total Homes</strong></td>
<td>Total</td>
<td>65</td>
<td>6,526&lt;sup&gt;3&lt;/sup&gt;</td>
<td></td>
</tr>
</tbody>
</table>

<sup>1</sup>U.S. Census Bureau, 2009-2013 5-Year American Community Survey

<sup>2</sup>Hopewell Township Tax Assessor’s Office
Results: Arsenic Treatment Systems

Arsenic Treatment Media

- Adedge
- Metsorb
- Resin Tech
- Isolux
- Solmetex/Layne
- Anion & Cation Beads
Results: Media in Arsenic Treatment Systems (n=65)
Results: Treatment System Components

- 68% had Softeners
- 85% of homes had a dual tank arsenic treatment system
- **42% had a complete system with all required components**

![Bar chart showing treatment system components](chart.jpg)
Results: “Who paid for your treatment system?”

- Previous homeowner: 58.5%
- Current homeowner: 32.3%
- NJ Spill Fund: 1.5%
- Split between Old & New Construction: 3.1%
- New Construction: 1.5%
- Other source: 3.1%
Results: Treatment Systems
Results: Treatment Systems
Results: Treatment Systems
Results: *Home-Owner Created Systems*
Many homes had softeners but they weren’t filled with salt

It is critical for some homeowners to keep them filled as it removes radium from the water.

Good example of why NJ does not recommend anion exchange for arsenic removal.
Results: Good Ideas by Treatment System Installers

- Water testing programs
- Labelling sampling ports
- Reminder post cards
- Installer contact info attached to system
Interesting Findings

- 37% thought boiling water would remove arsenic
- 62% thought Brita or refrigerator filtration removes arsenic
- 95% would take action if there was a change in taste, smell or appearance of water
- 88% know who to contact to test and treat their water
- 68% were confident that they would remember to regularly test their water (42% actually remember)
Arsenic Concentrations

Table 1. Summary of arsenic results.

<table>
<thead>
<tr>
<th></th>
<th>Raw (μg/L)</th>
<th>Between Arsenic Tanks (μg/L)</th>
<th>Kitchen Sink (μg/L)</th>
<th>Reverse Osmosis (μg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>11.3</td>
<td>3.7</td>
<td>1.1</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>StDev</td>
<td>9.0</td>
<td>6.1</td>
<td>2.3</td>
<td>0.00</td>
</tr>
<tr>
<td>Min</td>
<td>2.6</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>Max</td>
<td>41.6</td>
<td>38.5</td>
<td>12.8</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>(n = )</td>
<td>55</td>
<td>53</td>
<td>55</td>
<td>10</td>
</tr>
</tbody>
</table>
Arsenic Exposure

Table 3. Summary of arsenic exposure parameters and calculations.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mean</th>
<th>StDev</th>
<th>Min</th>
<th>Max</th>
<th>Total</th>
<th>(n = )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw water as concentration (μg/L)</td>
<td>11.3</td>
<td>9.0</td>
<td>2.6</td>
<td>41.6</td>
<td>620.8</td>
<td>55</td>
</tr>
<tr>
<td>Water consumed per day (L)</td>
<td>0.9</td>
<td>1.1</td>
<td>0.0</td>
<td>4.7</td>
<td>51.8</td>
<td>55</td>
</tr>
<tr>
<td>Beverages made with water consumed/ day (L)</td>
<td>0.7</td>
<td>1.1</td>
<td>0.0</td>
<td>7.1</td>
<td>39.4</td>
<td>55</td>
</tr>
<tr>
<td>Water + beverages consumed per day (L)</td>
<td>1.7</td>
<td>1.5</td>
<td>0.0</td>
<td>7.1</td>
<td>94.1</td>
<td>55</td>
</tr>
<tr>
<td>Water + beverages consumed per year (L)</td>
<td>624.9</td>
<td>555.5</td>
<td>0.0</td>
<td>2592.4</td>
<td>34368.6</td>
<td>55</td>
</tr>
<tr>
<td>Kitchen sink as concentration (μg/L)</td>
<td>1.1</td>
<td>2.3</td>
<td>&lt;0.1</td>
<td>12.8</td>
<td>59.5</td>
<td>55</td>
</tr>
<tr>
<td>Years in home</td>
<td>6.4</td>
<td>6.1</td>
<td>0.0</td>
<td>29.0</td>
<td>354.0</td>
<td>55</td>
</tr>
<tr>
<td>Years with treatment system</td>
<td>4.5</td>
<td>2.9</td>
<td>0.0</td>
<td>12.0</td>
<td>250.0</td>
<td>55</td>
</tr>
<tr>
<td>Anticipated future years in home</td>
<td>17.0</td>
<td>10.6</td>
<td>0.0</td>
<td>50.0</td>
<td>919.5</td>
<td>54</td>
</tr>
<tr>
<td>Past arsenic exposure prevented (mg)</td>
<td>23.5</td>
<td>29.7</td>
<td>0.0</td>
<td>136.1</td>
<td>1291.5</td>
<td>55</td>
</tr>
<tr>
<td>Future arsenic exposure prevented (mg)</td>
<td>78.7</td>
<td>97.9</td>
<td>0.0</td>
<td>626.5</td>
<td>4247.2</td>
<td>54</td>
</tr>
</tbody>
</table>

Only analyzed homeowners who had a dual-tank POET; one participant refused to answer anticipated years in home.
Risk Calculation

Equation 1: Risk

\[ Risk = Cancer\ Slope\ Factor \times Lifetime\ Average\ Daily\ Exposure \]

\[ Risk = CSF \times LADE \]

Equation 2: Average Risk from Drinking Raw Water

\[ Risk\ 0.0070 = 25.7 \left( \frac{mg}{kg \times day} \right) \times 0.00027 \left( \frac{mg}{kg \times day} \right) \]

Table 4. Risk calculation parameters.

<table>
<thead>
<tr>
<th>Exposure parameters</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Average water consumed per day (L)</td>
<td>0.94</td>
</tr>
<tr>
<td>Average beverages made with water per day (L)</td>
<td>0.72</td>
</tr>
<tr>
<td>Average water + beverages per day (L)</td>
<td>1.71</td>
</tr>
<tr>
<td>Total water consumed per year (L)</td>
<td>624.88</td>
</tr>
<tr>
<td>Arsenic cancer slope factor (mg/kg/d)</td>
<td>25.70</td>
</tr>
<tr>
<td>Population of Hopewell Township</td>
<td>17,304</td>
</tr>
</tbody>
</table>
### Risk Calculation

**Table 5. Lung and bladder cancer risk from arsenic in drinking water.**

<table>
<thead>
<tr>
<th></th>
<th>Raw</th>
<th>Between arsenic tanks</th>
<th>Kitchen sink</th>
<th>Achievable</th>
<th>Acceptable risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic concentration (µg/L)</td>
<td>11.16</td>
<td>3.65</td>
<td>1.45</td>
<td>0.050</td>
<td>0.0016</td>
</tr>
<tr>
<td>LADE (mg/kg/d)</td>
<td>0.00027</td>
<td>0.000089</td>
<td>0.000035</td>
<td>0.0000012</td>
<td>0.000000039</td>
</tr>
<tr>
<td>CSF</td>
<td>25.7</td>
<td>25.7</td>
<td>25.7</td>
<td>25.7</td>
<td>25.7</td>
</tr>
<tr>
<td>Risk</td>
<td>1 in 143</td>
<td>1 in 435</td>
<td>1 in 1,111</td>
<td>1 in 33,333</td>
<td>1 in 1,000,000</td>
</tr>
<tr>
<td>Lifetime risk applied to the Hopewell Township population</td>
<td>121.3</td>
<td>39.7</td>
<td>15.8</td>
<td>0.54</td>
<td>0.017</td>
</tr>
</tbody>
</table>
IS HOPEWELL TOWNSHIP’S ORDINANCE WORKING?
Is Hopewell’s Ordinance Working?

- In other NJ towns, homeowners are likely to install a single tank system.
- 80% of the homes with treatment systems in Hopewell exceed the MCL in their raw water.
- 25% of the homes exceed the standard after one treatment tank.
- 7% exceed the MCL after a second tank.
- All homes that have a reverse osmosis back-up system have arsenic at non-detect levels.
MCL Exceedances by Well Owner Characteristics

Sampling Locations and Homeowner Characteristics

- Raw
- Between Arsenic Tanks
- Kitchen Sink
- RO
Excess Lifetime Bladder and Lung Cancer Risk for Hopewell Township due to Arsenic in Drinking Water

No Treatment
121 lifetime cancer cases (1.7 cases/year)

1 Arsenic Tank
40 cancer cases (0.57 cases/year)

2 Arsenic Tanks
16 cancer cases (0.22 cases/year)

2 Arsenic Tanks and R.O.
Less than 1 cancer case
IS ARSENIC TREATMENT MEDIA BREAKING THROUGH?
Treatment Media Breakthrough

- All Treatment (n=61): 72.1%
- Metsorb (n=18): 61.1%
- Aedge (n=17): 76.5%
- Solmetex (n=19): 33.3%
- Resin Tech (n=6): 66.7%
- Softener (n=42): 50.0%

Treatment System Type:
- Treatment Media
- Treatment Media or Softener Beads
Arsenic Treatment Media: Adedge

- Granular Ferric Hydroxide (Adsorptive)
- Requires backwashing
- Lasts the longest
- Most expensive
- Breaks into small pieces
- Breakthrough in 77% of homes (n=17)

A. Unused adedge (7.5x)
B. Piece of adedge treatment media (64x)
C. Adedge treatment media found in toilet tank (As2015-002) (13x)
D. Various sizes of media on scale (size range; less than 10microns – 450 microns (64x)
Arsenic Treatment Media: Metsorb

- Titanium oxide
- Claims it does not need backwashing
- 2nd best capacity
- 2nd most expensive
- Breaks into very small pieces
- Breakthrough in 62% of homes (n=18)
Arsenic Treatment Media: Resin Tech

- Anion exchange resin beads
- Not uniform in size
- Lowest capacity
- Does not need to be backwashed
- Breakthrough in 33-66% of homes (n=6)

A. Resin tech beads in faucet filter (7.5x)
B. Resin tech bead from faucet (As2015-004), 0.4mm (64x)
C. Resin tech bead stuck in filter screen (64x)
Arsenic Treatment Media: Resin Tech Breakthrough

A. Resin tech beads on bathroom faucet filter screen
B–C. Resin tech beads coming out of faucet with filter screen removed
D. Resin tech beads from faucet
Arsenic Treatment Media: Solmetex

- Beads
- Hybrid ion exchange resins with hydrous iron oxides
- Does not backwash
- 3rd best capacity
- Beads break
- Breakthrough in 33-58% of homes (n=19)

A. Unused solmetex beads (21x)
B. Solmetex beads from As2015-024 toilet tank, a home without a softener, bead sizes range from 50-200 microns (64x)
Discussion: Main Findings

- 42% of participants had a complete system without any missing parts
  - (even with the Hopewell ordinance and a post installation inspection)
- 58% of homeowners reported that their arsenic system was installed by the previous homeowner
- Significant reduction in arsenic concentrations and cancer risk due to the presence of the systems (and the regulation)

- Two arsenic tanks (in series) should be the standard
- More towns should adopt this ordinance
- Current Homeowners (the “buyer”) needs to install
Discussion: Main Findings

Treatment media breakthrough is occurring in 72% of all homes sampled

- Add post-treatment sediment filter (5 micron)
- Alert manufacturers
- Have the Hopewell Ordinance revised to reflect this

Spayd, 2015
Public Health Actions

• Concerned neighbors were given detailed water testing instructions
• Participants given detailed results
  – Were told what specific steps they should take to ensure arsenic-free drinking water
  – Links to helpful websites and interest free water treatment financing information
• Salt tanks were filled
• Sediment filter changing assistance
• Arsenic questions answered
• Helped homeowners who should have had a maintenance contract contact the maintainer
Limitations

• Participation bias
• Hopewell Township, NJ is different than many NJ towns
• Recall Bias (daily exposure)

Strengths

• Unique ordinance with many opportunities to test existing systems in the same town
• Combined public health theory and practice
• Many opportunities for public health action
Arsenic Treatment Systems in Hopewell Township, N.J.

Additional Suggestions:

- Treatment installer certification training
- Arsenic treatment brochure
- Treatment tank labels
- Sampling port tags

Raw Water Sampling Port

Water sampled from this tap is untreated. You do not need to test your water from this location.

Between Arsenic Tanks Sampling Port

*TEST HERE YEARLY*

Remember to run 2 cold water taps for 10 minutes before taking a water sample. Replace your arsenic worker tank when the water from this tap reaches 5μg/L.
Arsenic Treatment Systems in Hopewell Township, N.J.
Summary

Hopewell’s ordinance will reduce the incidence of excess lifetime (70-year) arsenic-related bladder and lung cancers from 121 (1.7 cancer cases/year) to 16 (0.2 cancer cases/year) preventing 105 lifetime cancer cases in 70 years (1.5 cases/year)

Because the high risk of cancer from arsenic can be mitigated with effective arsenic water treatment systems, this ordinance should be considered a model for other municipalities.
Acknowledgements

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- Hopewell Township Study Participants

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Arsenic exposure and cancer risk reduction with local ordinance requiring whole-house dual-tank water treatment systems

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