Arsenic in New Jersey Well Water

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Disclaimer

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Partial Funding to Support This Investigation was Provided by Farmer Steve

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• Human Exposure Monitoring
Arsenic Health Issues

• Arsenic Causes Cancer in Humans at Doses Close to Drinking Water Concentrations in the United States.

• Unlike Many Other Chemicals, Arsenic Data are Sufficient so that there is No Need to Extrapolate From Animals to Humans or From Very High Doses to Low Doses.
Arsenic Health Effects

Based Mainly on Studies in Taiwan, Argentina, Chile, Bangladesh & Utah

- Cancer - Skin, Bladder, Lung, Kidney, & Liver
- Coronary Heart Disease
- Diabetes
- Skin Lesions - hyperpigmentation & keratosis
- Reproductive - miscarriage, stillbirth & infant mortality
- Respiratory Disease
- Hepatotoxicity
- Neurologic - Peripheral Neuropathy, Epilepsy
Palmer Hyperkeratosis
Planter Hyperkeratosis
Arsenic Health Issues

- The Dose/Response Curve.

- 1 per million excess cancer risk goal verses 3,000 per million excess cancer risk at 10 ppb.

- Is There a Threshold Level?
The Arsenic MCL Story

• 1942 - Level of 50 ppb initially set

• Much Controversy...

• Feb 2002 - USEPA MCL Set at 10 ppb
Christy Whitman Stars in Arsenic and Old Lace

YOU POOR DEAR! WORRYING ABOUT CO₂ EMISSIONS AND GLOBAL WARMING AND ARCTIC DRILLING! HERE... HAVE A NICE GLASS OF WATER!

Arsenic & Old Lace
Arsenic MCL in New Jersey....

NJDEP proposed an MCL of 10 ppb in January 2002.

Many comments were received pushing for a lower MCL in New Jersey.

The NJDWQI has recommended that NJ set its MCL for arsenic below 10 ppb.
How Did I Get Interested in Arsenic?

- 1998 - NJGS/USGS Needed Wells in the Piedmont to Sample.
- I volunteered and They Sampled My Well.
- Arsenic at 57 ppb - the Highest Level of All Wells Tested in NJ for the Next 3 Years.
- Confirmed by Multiple Labs & Methods.
MEANWHILE IN MEXICO...

Estamos vayando a la casa de Esteban.  ¡No beben el agua!
• Water from 175-foot deep well.
• pH is in the 7.5 - 7.8 range.
• Dissolved oxygen is very low, generally < 0.2 mg/L.
• Arsenic is 95% arsenate (As5) at this well.
NJ Public Wells Confirmed to Exceed 10 ppb Arsenic
Arsenic & Geology in NJ
Action Plan

Arsenic is a Problem in NJ

Source(s)
- Natural
- Anthropogenic

Remediation
- Water Treatment
- Well Retrofitting

Health Issues
- Potential Advisory Areas
- Exposure Assessment & Biomonitoring

Health Issues

Arsenic is a Problem in NJ
Source Investigation

Anthropogenic (Man Made)

• 15 Million Pounds of Arsenic Used in NJ as Pesticides from 1900 - 1980
• Also Used as a Wood Preservative

Natural

• Arsenic is a Fairly Abundant Element
• Found in Pyrite Crystals in NJ
Source Investigation

- Ambient Data
- Public Well Data
- Rock Core
- Packer Tests
- Heat Pulse Flow Meter
Hydrologic Cycle

• King Solomon (1000 BC)
  “All the rivers run into the sea, yet the sea is not full…”

• Leonardo da Vinci (1452-1519)
  “…all the sea and rivers have passed through the mouth of the Nile an infinite number of times…”
The Hydrologic Cycle

The continuous hydrologic cycle.

bgd = billion gallons per day
Where Does the Well Water in Hopewell Come From?

a) An underground river from Canada.
b) An underground river from the Adirondacks.
c) An underground river from the Poconos.
d) None of the above.

The correct answer is d) None of the above.

Our well water actually comes from recharge at the land surface.
WHAT IS A WELL HEAD?

Some potential sources of ground water contamination. Source: Adapted from Paly and Steppacher, n.d.
Well Drilled into Fractured Rock Aquifer

FIGURE 7.32. Concentration of groundwater along zones of fracture concentrations in fractured rock.
Direction and rate of ground-water movement.
Unweathered Pyrite Crystals on Freshly Broken Bedrock Surface

Weathered Pyrite Crystals on Weathered Bedrock Fracture Surface

*prize*
Core Sample From Hopewell Township, New Jersey

- Sample of black shale from 148.2 feet below land surface
- Pyrite in green circle has 11,500 ppm arsenic
- Pyrite in yellow circle has 15,860 ppm arsenic
- Nearby well water has arsenic concentrations ranging up to 48 ppb

Magnified 750X

Scanning electron micrograph of a thin section

Slide courtesy of Mike Serfes, NJGS
Gray Shale Bedrock of the Lockatong Formation
Arsenic versus dissolved oxygen and pH from study area. This is a compilation of data from all the formations sampled. Note that a DO < 3 mg/L increases the probability (visual assessment) of having an arsenic concentration greater than 10 ug/L. A pH between 7.5 and 8.2 may also be an optimal range for arsenic mobility. More work needs to be done to better define these and other indicators.
Alkalinity versus Arsenic at Stony Brook

\[ y = -1.9358x + 176.01 \]

\[ R^2 = 0.2438 \]
Arsenic Species: 
As3 (arsenite) & As5 (arsenate)

- Arsenic species testing is not commercially available

- Arsenic species affects treatment ability
Arсенic Speciation in New Jersey

Cooperative study testing the wells with the highest arsenic levels in NJ.

NJGS, USGS, Stevens Institute of Technology, and the Environmental and Occupational Health Sciences Institute of UMDNJ/Rutgers.

Tested 28 wells (public and residential) with the highest known arsenic levels in NJ. Four labs using a variety of speciation methods found very comparable results.

Only 4 wells (14%) had As3 above 2 ppb. All of these wells were in the Lockatong Fm.
Remediation Issues

• Water Treatment
• Point of Use vs Point Of Entry
• Treat Whole House or Just Drinking Water
• Arsenic Species (As5, As3)
• Well Retrofitting
• Well Sampling Alerts
• Homeowner’s Arsenic Guide
Treatment Technologies Tested

- Reverse Osmosis for Point of Use
- Granular Ferric Hydroxide (GEH, GFH)
- Anion Exchange Resin
- Apyron Aqua-Bind XP
- Apyron Aqua-Bind MP
- Greensand
- KDF-55
- KDF-85
- Granular Ferric Oxide (GFO)
- Other Experimental Media

We have not tested everything.
**ARSENIC WATER TREATMENT TESTING**
**COMPARISON OF POOR PERFORMERS**

**Pilot Testing**

**GALLONS THROUGH SYSTEM**

**ARSENIC CONCENTRATION (PPB)**

- Greensand
- KDF-55
- KDF-85
- Sadat
- Aquatronics
ARSENIC WATER TREATMENT TESTING
COMPARISON OF FOUR TOP PERFORMERS

Pilot Testing

GALLONS THROUGH SYSTEM

ARSENIC CONCENTRATION (PPB)

0 5000 10000 15000 20000 25000

Anion Exchange  GEH  Apyron XPL  Apyron MPL
What’s Needed in an Arsenic Water Treatment System for a Home?

• User Friendliness
• Low Maintenance
• Cost Effectiveness
• Efficiency
• Safety
Reverse Osmosis Treated Water During Pilot Testing

Equipment used was an RO Cartridge Type Thin-Film-Composite (TFC) Membrane with Pre and Post filters.
Five liters of resin were used during pilot testing.

Levels above 60 ppb are the result of arsenic dumping by resin due to sulfate competition.
Anion Exchange

(Strong Base Anion Type II Resin)

Treated Water During POET Testing

One Cubic Foot of Resin Used During POET Scale Testing. EBCT at a Minimum of Two Minutes.

All Samples of Treated Water Via Anion Exchange With up to 4,102 Gallons Between Regenerations Were Below the Method Reporting Limit of 2.0 ppb. Total Water Treated to Date is 134,000 Gallons

Gallons Treated After Regeneration With Salt
Anion Exchange Treatment Notes:

Anion Exchange treats only arsenate (As$_5$). Pre-treatment is required if arsenite (As$_3$) is present. Treated water pH is in the 5.0 - 6.8 range when regenerated properly.

System is regularly regenerated with salt. If the system is not regenerated on the proper schedule, "dumping" of arsenic into the treated water, at levels above the raw water concentration, will occur due to sulfate, nitrate, or other anion loading.

Because this system does not remove As$_3$, it is not recommended for use in NJ. It should only be used if As$_5$ has been determined to be the predominant species in the water. Pre-treatment systems to convert As$_3$ to As$_5$ are available, but are not recommended for the average home because of their high cost, complexity, and need for maintenance.
Granular Ferric Hydroxide (GFH™) Treated Water During POET Testing

The Maximum Concentration Detected From All Samples of Treated Water Via Granular Ferric Hydroxide Media through 60,502 Gallons or 8,089 Bed Volumes, was 2.6 ppb.

One Cubic Foot of Resin Used During POET Scale Testing. EBCT at a Minimum of Two Minutes.
Granular Ferric Hydroxide Treatment Notes:

This media treats both arsenate (As5) and arsenite (As3) without pre-treatment in NJ.

Low maintenance.

No arsenic is returned to the environment near the home.
Granular Ferric Oxide
Treated Water During POET Testing

The Maximum Concentration Detected From All Samples of Treated Water Via Granular Ferric Oxide Media through 92,704 Gallons or 12,394 Bed Volumes, was < 2.0 ppb. EBCT = 2-3 Minutes
Granular Ferric Oxide Treatment Notes:

This media treats both arsenate (As5) and arsenite (As3) without pre-treatment in NJ.

The media ships dry and is less dense than GFH.

Low maintenance.

No arsenic is returned to the environment near the home.
Granular Titanium Dioxide Treated Water During Recent Pilot Testing

![Graph showing As levels over bed volumes.](image-url)
A whole-house granular ferric adsorption system is the preferred treatment technology because it effectively removes both arsenic species from all water in the home, it is easy to operate and maintain, and the arsenic is not returned to the environment via regeneration.
Granular Ferric Adsorption Whole-House Treatment System Schematic

[Diagram of the system with labels:
- RAW WATER
- SHUT OFF VALVE
- PREFILTER
- SAMPLING PORT
- TREATED WATER
- Tank #1
- Tank #2
- Backwash Valve
- Media Tank

Fig. 2]
Reverse Osmosis and Adsorption Media Cartridges may be viable options.

Disadvantages:

• arsenic exposure may continue in the home from other water uses, especially drinking from other taps, and

• it is not uncommon for homeowners to over run the useful life of point-of-use cartridges.
Human Exposure to Arsenic and Biomonitoring of the Families with the Highest Known Arsenic Levels in New Jersey Well Water - Preliminary Data

Brian Buckley, PhD, Principal Investigator, EOHSI & Steve Spayd, MPH Student
University of Medicine and Dentistry of NJ
School of Public Health
Why an Interest in Exposures From Other Than Drinking or Cooking With the Water?

• Though drinking and cooking with arsenic contaminated water is obviously the main exposure pathway in the home, other exposure pathways may exist (e.g., showering & brushing teeth).

• Because even low levels of exposure are estimated to result in typically unacceptable cancer risks, these other exposures may represent a significant risk when arsenic water concentrations are above a certain level.
Figure 2-9. Existing Information on Health Effects of Inorganic Arsenic

<table>
<thead>
<tr>
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<th>Death</th>
<th>Acute</th>
<th>Intermediate</th>
<th>Chronic</th>
<th>Immunologic/Lymphatic</th>
<th>Neurologic</th>
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Source: ATSDR
Figure 2-7. Parameters Used in the Mann PBPK Model for Humans

Source: Mann et al. 1996b
Human Exposure Study Design

- Identify the families with the highest known arsenic levels in NJ well water.

- Obtain samples of urine, blood, and hair before and after arsenic exposure is reduced.

- Some families still drinking the arsenic contaminated water, some families drinking and cooking with bottled water or Point-of-Use treated water, and some families obtaining whole-house (Point-of-Entry) treatment of their water.

- Continue biomonitoring with time.

- Compare results between the different groups to see if there is a significant difference.
### Table 4

<table>
<thead>
<tr>
<th>Drinking Water</th>
<th>Blood</th>
<th>Urine, Total As</th>
<th>Urine, Inorganic As + DMA+MMA</th>
<th>Location</th>
<th>Data Source</th>
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<td>75</td>
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<td>1.5</td>
<td>55</td>
<td>45</td>
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<td>30</td>
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<td>-</td>
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<td>Wyatt, et al., 1997</td>
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<td>59</td>
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<td>14</td>
<td>1.5</td>
<td>34</td>
<td>24</td>
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<td>1.2</td>
<td>20</td>
<td>13</td>
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</table>
Father & Mother
Urine Data

Arsenic Concentration in Urine (micrograms/gram of creatinine)

- February 1, 1999: 58.0
- November 16, 2000: 18.2
- July 17, 2001: 8.1
- July 25, 2001: 6.0

Father: Blue  Mother: Red

Whole-House Water Treatment Begins

1.7 Years

8 months

8 days
Daughter #3
Urine Data

Arsenic Concentration in Urine (micrograms/gram of creatinine)

Whole-House Water Treatment Begins

Date A - February 1999
Date B - November 2000
Date C - July 17, 2001
Date D - July 25, 2001

15.1
10.2
6.6

1.7 Years
6 months
8 days
Not Tested
The reduction in urine arsenic level from 7/17/01 to 7/25/01 was found to be statistically significant with $p = 0.03$ as analyzed by Wilcoxon Matched Pair Signed Rank Test.
Arsenic Speciation

DMA, As3, MMA, As5 @30 ppb

As Chromatograph of Urine of Daughter J. Doe
The Latest Arsenic Biomonitoring Data

Not Available Yet
# Water Quality From Packer Test

<table>
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<tr>
<th>Depth</th>
<th>Arsenic</th>
<th>Pump Below Packer</th>
<th>Depth</th>
<th>Arsenic</th>
<th>Pump Above Packer</th>
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<tbody>
<tr>
<td>62-175</td>
<td>58 ppb</td>
<td></td>
<td>50-61</td>
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<td>82-175</td>
<td>58 ppb</td>
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<td>50-81</td>
<td>50 ppb</td>
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<tr>
<td>122-175</td>
<td>58 ppb</td>
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<td>50-121</td>
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<td>57 ppb</td>
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<td>50-161</td>
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# Heat Pulse Flow Meter Data

## Data Summary

### Pumping at 11.3 GPM

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<th>Relative Median Flow Rate [gpm]</th>
<th>Major Joints on Caliper</th>
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<td>7.50</td>
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<td>56.05</td>
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<td>102.00</td>
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<td>116.00</td>
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<td>100 *********</td>
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<td>130.10</td>
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<td>114 *** &amp; 126 ***</td>
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<td>150.00</td>
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<td>168.05</td>
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</table>

### Borehole Schematic

- 45.00 ft
- 56.05 ft
- 102.00 ft
- 116.00 ft
- 130.10 ft
- 150.00 ft
- 164.05 ft
- 168.05 ft
# Heat Pulse Flow Meter Data

## Data Summary

<table>
<thead>
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<td>168.05</td>
<td>0.00</td>
<td>165 *******************</td>
</tr>
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Raw Water Arsenic Concentrations
Since Grouting the Well to a Depth of 94 Feet

At this rate, arsenic should reach non-detectable levels within 6 years.
Summary

• Levels of arsenic in New Jersey residential wells range up to 200 ppb.
• As3 is a problem at 10-20% of the wells.
• The arsenic in well water appears to be attributed to natural geologic sources in the Piedmont Physiographic Province.
• More than a dozen arsenic water treatment technologies have been tested.
• Based on our studies to date, granular ferric adsorption is currently the preferred treatment choice in New Jersey.
• An arsenic human exposure study is ongoing and may indicate the need for whole-house treatment above a certain level of arsenic in well water.
Acknowledgements

Any Questions?
Partial Funding to Support This Investigation was Provided by Farmer Steve

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