Arsenic variability and geochemistry at a domestic bedrock well in New Hampshire

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Objectives

1. Over what time scales does water quality change?

2. What are the drivers of change?
   1. Geochemical processes
   2. Groundwater age
Background-
Arsenic in New England

From Flanagan and others (2012)
Background - Setting

KFW-87

A. Bedrock Geology

B. Surficial Geology

Explanations:
- Exeter Diomite
- Berwick Formation
- Flite Formation
- Kittery Formation
- Newburyport Complex (late Silurian)
- Newburyport Complex (early-late Silurian)

- Marine silt and clay
- Till
- Wetlands
- Ocean
- Bedrock
Background - Geophysical Log

- Various (5+) fracture zones
- Generally, >100 feet depth

![Geophysical Log Diagram]

- Specific Conductance
- Temperature
- Caliper
Background - Summary

- High arsenic occurs in locations with both:
  - Sources of arsenic (calcareous metasedimentary rock)
  - Geochemical state conducive to arsenic mobility

Low DO and high pH are arsenic’s happy state!*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>pH (standard units)</th>
<th>DO (mg/L)</th>
<th>As (ug/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median</td>
<td>8</td>
<td>0.1</td>
<td>37.2</td>
</tr>
</tbody>
</table>

*Ayotte and others (2003), Bondu and others (2017), Flanagan and others (2012)
Methods - Sampling

Continuous
- pH
- Specific conductivity
- Water temperature
- Dissolved oxygen
- Water level

Discrete
- Major ion chemistry
- Alkalinity
- Nutrients
- Arsenic and other trace elements
- As(III) and As(V) species
- Radionuclides
- Stables isotopes
- Age tracers
- Atmospheric gases

https://waterdata.usgs.gov/nwis/
Analysis - Correlations

ALWAYS ANOXIC! (DO <0.5 mg/L)

DO decreases when water level is up –

More anoxic water with recharge

Spearman’s rho=0.43
p<0.001
Analysis - Correlations

More arsenic with recharge
Analysis - Redox Processes

Terminal Electron-Accepting Processes (TEAP)

More reduced water with recharge
Analysis - Age distributions

Jurgens and others (2012)

Older water with recharge?
Going Forward – Further Analysis

- Trend
  - Occurs over sampling period
  - Repeating or monotonic

- Event
  - Occurs once
  - High or low value
Trends and Events

Arsenic Species

As (μg/L)

As(III) vs. As(V)

Calendar year

Date

Citrate

Manganeso (μg/L)

Calendar year

Date

Tableau 1

Tableau 2

Tableau 3

Tableau 4

Tableau 5

Tableau 6
As Species and Drought

- **As(V)** vs. **As(III)**, ug/L
- Rank sum test
  \( p = 0.007 \)

**Graphs:**
- Left: Time series of As(V) - As(III) from 2015 to 2017.
- Right: Precipitation before and after a drought event.
Further Analysis – Age Dating

**Arsenic correlates**

\( \rho = 0.81, p < 0.001 \)

**Young and old ages correlate**

\( \rho = 0.53, p < 0.05 \)

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**Glacial**

**Bedrock**
Summary

• Highest arsenic occurs with high water levels (seasonally)
• Secondary arsenic peak at lowest water levels
• Arsenic highs are related to lower redox state (more reduced)
• Drought causes spikes and troughs in chemical constituents
• Age distributions were not particularly informative, other than as evidence of modern recharge.

• May not be indicative of all wells in the area
  • BUT similar patterns seen at 2 nearby public supply wells in network.
Questions?

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