Insights from the NJ Private Well Testing Act Database

Focus on Coliform Bacteria

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NJ Water Monitoring Council
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CDC Yearly U.S. Estimates:

- Disease estimates from public drinking water sources: 4-32 million cases.

- There are no estimates for private wells.

- Perspective: foodborne disease: 48 million cases; 128,000 hospitalizations, and 3,000 deaths.

- U. Arizona researchers found more fecal bacteria in the kitchen (sponges, dish towels, sink drain, countertops) than from swabbing the rim of the toilet.
NJ Water Stats

- **NJ Population:** 9 million (2017 est.)
  - 1218 per square mile (2015 data); highest in US.
  - ~88% obtain water from highly regulated **public** water systems.
  - ~12% from 400,000 **private** (domestic) wells.

- No **federal** regulations cover private wells.

- **Before 2002:** **state** regs applied only to newly-constructed wells.

- Ocean Co & a few municipalities had their own regulations.
NJ Private Well Testing Act

- Became effective 9/16/2002.

- Real estate with wells. Untreated well water must be tested during real estate transactions for 34 or 35 parameters (county-dependent).

- Testing done by private, state-certified labs. Cost paid by seller or buyer (~$450-600).

- Results provided to client and submitted electronically to the NJDEP.

- No action required if a parameter limit is “exceeded” (a right-to-know law).
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Recommended Limit (a)</th>
<th>RL Origin (b)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Bacteriological</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Coliform (c)</td>
<td>0 /100 ml (FC or E. coli)</td>
<td>S-RL</td>
</tr>
<tr>
<td><strong>Organic chemicals</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26 volatile organic chemicals</td>
<td>see Table 2</td>
<td>F&amp;S-MCL</td>
</tr>
<tr>
<td><strong>Inorganic chemicals</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrate/nitrite (as nitrogen)</td>
<td>10 mg/L</td>
<td>F-MCL</td>
</tr>
<tr>
<td>Lead</td>
<td>10 µg/L (to 11/6/05); 5 µg/L (after 11/6/05)</td>
<td>S-GWQS</td>
</tr>
<tr>
<td>Arsenic (d)</td>
<td>10 µg/L (to 1/22/06); 5 µg/L (after 1/22/06)</td>
<td>S-MCL</td>
</tr>
<tr>
<td>Mercury (e)</td>
<td>2 µg/L</td>
<td>F-MCL</td>
</tr>
<tr>
<td><strong>Radiological</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>48-h gross alpha particle radioactivity (f)</td>
<td>15 pCi/L</td>
<td>S-MCL</td>
</tr>
<tr>
<td><strong>Secondary</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>6.5 - 8.5</td>
<td>F-OP</td>
</tr>
<tr>
<td>Iron</td>
<td>0.3 mg/L</td>
<td>F-RL</td>
</tr>
<tr>
<td>Manganese</td>
<td>0.05 mg/L</td>
<td>F-RL</td>
</tr>
</tbody>
</table>

(a) Units: ml = milliliter; µg/L = microgram per liter (part per billion); mg/L = milligram per liter (part per million); pCi/L = picoCurie per liter.

(b) The NJDEP adopted a federal (F) standard or derived its own state (S) standard. RL = recommended limit; MCL = Maximum Contaminant Level; GWQS = Ground Water Quality Standard; OP = optimum range.

(c) If Total coliform test positive, sample tested for either fecal coliform (FC) or E. coli. The RL is exceeded if FC or E. coli are detected.

(d) Testing required in 12 northern and central counties only.

(e) Testing required in 9 southern counties only.

(f) Testing required in 12 southern and central counties only. 24-h test: if > 5 pCi/L, tested again at 48-h. If > 15 pCi/L, MCL exceedence.
As of Sep 20, 2012:
- 78,547 Wells
- 93,787 Samples
- 10 Years of Data
Uncorrected Well Locations

Several People, Several Years To Correct Well Location Information
Location Corrections: are based on block and lot

- **PLEASE:**
  - If the block is 675 and the lot is 5, do not reverse them.
  - If the lot is 2.05, do not write 2, or 2-5, or 2.5.
  - Several towns changed their block and/or lot numbering systems making our job that much more fun!

- **ALSO:**
  - Do not reverse X & Y coordinates, or make them up out of thin air.
  - After taking GPS coordinates, please correct the numbers using appropriate reference (base) stations.
  - Spelling is important, you wouldn’t buy a shirt without the r. If it’s Maple Road, don’t write Maple Drive (although this is less important).
Data Limitations and Strengths

Limitations

- Sampling untreated water but many samples collected after holding/pressure tanks.
- No well construction or detailed hydrogeological information (except pH) including well depth.
- Number of data errors unknown (no QC).

Strengths

- Large database, data submitted by 35 labs (21 currently active).
  - No. samples per lab: median = 515 (range = 1 - 11,770).
  - No. labs that submitted data from 75 or more samples = 30.
- Little or no sample/well selection bias.
  - Water quality = none.
  - Well location and time of sampling = minimal.
- Well location and coliform test method information corrected & reasonably accurate.
Number of Samples Collected Per Workday For Each Month

![Graph showing the number of samples collected per workday for each month from 2002 to 2013. The x-axis represents the year, and the y-axis represents the samples per workday. The graph shows a general decrease in samples collected per workday over the years, with some variability.](image-url)
PWTA Coliform Regulation

- Test untreated water for **Total Coliform (TC)** bacteria.
- If TC-positive, must test the TC-positive sample for **Fecal Coliform (FC) OR E. coli (EC)** bacteria.
- If FC or EC are present = an “exceedence.”
  - “The well may contain fecal contamination and hence may contain disease-causing microorganisms.”
- Presence/absence (quantitative test not required).
- Result valid for 6 months.
Relationship of Coliform Groups

Total Coliform Bacteria
(Enzyme Substrate Tests: Colilert, Colisure, etc)

(Fermentation Tests: MTF, MF)

(E. coli, Enterobacter, Klebsiella, Citrobacter, Serratia, Leclercia, Yersinia, + other genera)

(sewage ~ 10-20 x 10^7 / 100 ml)

Fecal Coliform Bacteria

(E. coli, Enterobacter, Klebsiella)

(~2-9 x 10^6 / 100 ml)

E. coli

(~1-6 x 10^6 / 100 ml)
CS = Chromogenic Substrate Test (e.g., Colilert).
MF = Membrane Filtration Test (e.g., SM9222B).
Ferm = Broth Fermentation Test (e.g., SM9221B).
Coliform Bacteria in Private Wells: The Probability of Detection Depends on:

- Well integrity and proper construction, including disinf. & flushing of new wells.
- Well depth.
- The laboratory and the method used.
- The lithology and aquifer pH.
- Significant precipitation.
- In bedrock: proximity to lakes, high nitrate.
- No. times a well is sampled.
- The time of year the well is sampled.
Data after 6 Months

Private Well Testing Act
Results from September 2002 - March 2003
Fecal Coliform/E. coli Results

digital cartography by Terri Asherheit
and Gail Carter, NJDEP - DSRT, September 2003
Data after 2 Years

No. Fecal Col/E coli - Positive Wells = 551
No. Wells Tested (once only) = 26,064
Figure S9
pH of Private Wells in NJ

- pH:
  - <4
  - 4-4.99
  - 5-5.99
  - 6-6.99
  - 7-7.99
  - 8-8.99
  - >9

- PROVINCE:
  - Coastal Plain
  - Highlands
  - Piedmont
  - Valley and Ridge
  - Counties

- pH Legend:
  - Fall Line
  - Aquifers
  - pH Ranges:
    - 4.15 - 5.49
    - 5.49 - 5.99
    - 6.00 - 6.49
    - 6.49 - 6.99
    - 7.00 - 8.62

- Scale:
  - 0 - 25 - 50 - 100 Kilometers
Lithology

Vulnerability to Coliform Contamination:

- Carbonaceous sedimentary rock
  - (limestone, dolomite)
- Non-carbonaceous sedimentary rock
  - (sandstone, siltstone, mudstone, shale, argillite)
- Igneous and Metamorphic rock
  - (granite, basalt, gneiss)
- Coastal Plain
  - (alt. layers of sand, silt, and clay)
TC = Total Col.
FC = Fecal Col.

TC = solid or thick-hatched bars.
FC/E. coli = open or thin-hatched bars.
Numbers = no. wells tested.
x different than xx (p < 0.05)
**pH:**

Bedrock Provinces

Coastal Plain
Figure S2
Multi-sensor Precipitation Estimator (MPE) Rainfall Totals (cm) for July 15, 2004

Legend
- 0.00 - 0.25
- 0.26 - 0.64
- 0.65 - 1.27
- 1.28 - 2.54
- 2.55 - 5.08
- 5.09 - 32.79

Counties
Figure 9a. Bedrock Provinces
Rainfall Total on the Sample Day and the
Percentage of Wells With Fecal Coliform or E. coli Bacteria
April - November

Data is the average of 29 monitoring stations.
Numbers = number of available days.

Average Total Rainfall on Sample Day (cm)

Figure 9b. Bedrock Provinces
Number of Dry Days Preceding a Dry Sample Day* and the Percentage of Wells
With Either Fecal Coliform or E. coli Bacteria
April - November

* No rain at any of the 29 monitoring stations.
Numbers = number of available days.
Proximity to Lakes in Bedrock Region

![Graph showing the percentage of positive wells based on distance from waterbodies.]

- Lakes in the Bedrock Provinces
- Lakes in the Coastal Plain
- Rivers in the Bedrock Provinces
- Rivers in the Coastal Plain
High Nitrate in Bedrock Region

Percentage of Wells With Total Coliform Bacteria
At the Indicated Nitrate/Nitrite Concentration Range

- Bedrock Provinces
- Coastal Plain
The Number of Times a Well is Sampled

Estimated $p = 1 - (1 - \text{[first sample } p])^x$

$x = \text{the number of samples}$
Estimated number of samples required before coliform bacteria are detected in 25%, 50%, 75%, 90%, and 95% of the indicated well populations

<table>
<thead>
<tr>
<th>Region, test used, and geologic subset (a)</th>
<th>Total Coliform Bacteria</th>
<th>Fecal Coliform or E. coli Bacteria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25%</td>
<td>50%</td>
</tr>
<tr>
<td><strong>Bedrock Provinces</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td><strong>Wells tested with either a MF or FERM test</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Wells in igneous or metamorphic rock between pH 7 and 10</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td><strong>Wells tested with an ES test</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Wells in sedimentary rock between pH 3 and 6</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td><strong>Coastal Plain</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td><strong>Wells tested with either a MF or FERM test</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>5</td>
<td>13</td>
</tr>
<tr>
<td>Wells with pH between 3 and 6</td>
<td>8</td>
<td>18</td>
</tr>
<tr>
<td><strong>Wells tested with an ES test</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>Wells with pH between 6.25 and 10</td>
<td>3</td>
<td>6</td>
</tr>
</tbody>
</table>

(a) MF = membrane filtration, FERM = fermentation, ES = enzyme substrate test (see Table1).
Seasonality

PWTA Data

Data from England

Fig. 1 - Percentage of water samples with E. coli by week of year.

Fig. 2 - Percentage contamination of private water supplies by week 1996-2003.

Data from British Columbia, Canada

Percentage of Wells in Which Total Coliform Bacteria Were Detected

Bedrock Region

Fermentation or Membrane Filtration Method

Enzyme Substrate Method

Coastal Plain

Membrane Filtration Method

Enzyme Substrate Method

Percentage of Total Coliform-Positive Wells

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
E. Coli doubling times:

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Doubling Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>no growth</td>
</tr>
<tr>
<td>10</td>
<td>10 h</td>
</tr>
<tr>
<td>15</td>
<td>2 h</td>
</tr>
<tr>
<td>20</td>
<td>&lt; 1 h</td>
</tr>
<tr>
<td>30</td>
<td>30 min</td>
</tr>
</tbody>
</table>

(T. Brock. The Biology of Microorganisms, 1970)

Evidence of surface influence and that coliforms can and do multiply during warm periods.
Hypothesis:
The source of some coliforms may be at or near the well itself

**Take Home Message**

- **A single sample** is insufficient to reliably detect coliform bacteria.

- A positive **total coliform** result may not indicate the presence of fecal contamination.

- Significant precipitation (≥ 2.1 cumulative inches 10 days prior to sampling) increases the fecal coliform or E. coli detection rate.

- **Most if not all wells in bedrock appear vulnerable to coliform contamination.**
  - Should all well owners in bedrock be advised to disinfect their wells? If so, what equipment should be recommended?
Questions

- Because of the seasonality of detection rates: are the coliforms, including E. coli, derived from fecal contamination sources (septics, sewage collection lines) or are they indigenous members of soils and sediments?

- Would improved grout materials and methods reduce contamination rates?
References