Groundwater Quality and Public Health in Areas of New Mexico Utilizing Onsite Wells and Septic Systems

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Sewage Management in New Mexico

Statewide
- Public sewer
- Septic tank, cesspool
- Privy, other

Bernalillo County
- Public sewer
- Septic tank, cesspool
- Privy, other

Catron County
- Public sewer
- Septic tank, cesspool
- Privy, other

McKinley County
- Public sewer
- Septic tank, cesspool
- Privy, other
On-Site Systems in NM

- ~235,000 household septic systems (septic tanks and cesspools), with ~4000 new systems/year
- ~88 million gallons per day of wastewater discharged to the subsurface
- most of this wastewater eventually percolates to ground water
- many areas using septic systems also rely on private wells for domestic supply
Septic System Suitability

- Septic systems are a suitable means of on-site waste disposal when site conditions are favorable for natural attenuation, however,
Septic System Suitability

• "The development of fringe areas and subdivisions that do not have access to municipal water and sewage facilities is creating a continuously growing problem in proper protection of the public health in these areas. ... Septic tanks and leaching systems were never intended for use in closely built-up areas." (NM Board of Public Health, 1959)
Potential Problems

- Hazards to public health and safety
- Entrapment, drowning, and asphyxiation in illegal cesspools or substandard septic tanks
- **Pollution of water supply wells**
- Surfacing sewage
- Degradation of surface water quality
- Interference with public welfare and property rights
The Capacity for Natural Attenuation is Finite
“Household septic tanks and cesspools constitute the single largest source of ground water contamination in the state.”
Contaminated* Wells in N.M.

*Chemical constituent above numerical standard or fecal coliform detection.
Potential Groundwater Contamination

Onsite wastewater systems can contaminate groundwater with:

- **Pathogens***
- **Nitrate***
- Anaerobic respiration byproducts
  - Iron,
  - Manganese,
  - Hydrogen sulfide
- Organic compounds
  - Aromatic and chlorinated VOCs
  - Ethers, ketones
  - Pharmaceuticals

*Subject of health-related field investigations in N.M.
Waterborne Disease

- Notifiable diseases or conditions.
- Acute Disease Response Team investigates outbreaks of food or waterborne illness.
- Cause of illness is not always determined.
- Potential exposure sources include drinking water, food, recreational water, poor hygiene.
1985 Study

- Albuquerque South Valley, high percentage of homes served by onsite wells and septic systems.
- Allegations of epidemic of giardiasis.
- State Health/Environment Dept. study funded by legislature.
- Gallaher et al., 1987.
- Active surveillance system for diarrheal disease.
1985 Study – Case Definition

- Patients seeking health care for diarrheal disease, May to September 1985, were asked to submit stool specimen.
- Case defined as patient with positive stool detection of amebiasis, campylobacteriosis, cryptosporidiosis, giardiasis, salmonellosis, or shigellosis.
1985 Study – Control Definition

- Patients seeking health care at same clinic for condition other than diarrheal illness.
- Three controls selected for each case identified.
1985 Study – Questionnaire

Questionnaire administered to all study participants regarding:

- demographic info;
- time of residence at current address;
- whether patient had experienced vomiting and/or diarrhea; and
- 23 questions about risk factors for diarrheal illness.
1985 Study – Water Testing

For each case and control served by a private well, water samples were collected for:

- fecal coliform;
- general chemistry;
- trace elements; and
- nitrogen species.
1985 Study – Results
40 cases of confirmed illness

- Amebiasis
- Campylobacteriosis
- Cryptosporidiosis
- Giardiasis
- Salmonellosis
- Shigellosis
1985 Study – Results
Diarrheal Illness Rate

- 74 per 100,000 in ABQ South Valley
- 66 per 100,000 statewide
1985 Study – Results
Risk Factors for Diarrheal Illness

- Instate travel
- Eating at restaurant, party or banquet
- Consumption of raw milk
- Consumption of raw meat or poultry
- Swimming in river, lake or ditch
Consumption of private domestic well water was not found to be a risk factor.
Fecal coliform not detected in any private well.

Logistic regression analysis found that no water chemistry parameter served as a predictor for diarrheal illness.

Regional groundwater geochemistry and redox conditions, including influences from onsite wastewater discharges, were defined.
2008-09 Study

- Communities in Albuquerque area served by onsite wells and septic systems: basin fill sediment and fractured/weathered bedrock.

- *Cryptosporidium* antibodies used as an indicator of an immune response that may be caused by contaminated water.

- University of New Mexico and Lovelace Institute study funded by Association for Prevention Teaching and Research.

- Jackson, 2009.
Cryptosporidium

- Common waterborne protozoan parasite.
- Cause of infectious gastroenteritis characterized by watery diarrhea.
- Some 403,000 people were sickened in Milwaukee in 1993 when Cryptosporidium oocysts in water from Lake Michigan passed thru the drinking water treatment works.
- Cryptosporidiosis is believed to be an underreported condition.
2008-09 Study - Methods

- Blood testing for *Cryptosporidium* antibody.
- Well water testing for: total coliforms, *E. coli*, *Enterococcus*, and somatic coliphage.
- Questionnaire
People with wells/septics on basin-fill site had more intense serological response to *Cryptosporidium* antigen, after controlling for other risk factors, than the users of city water and sewer.
Repeat Water Sample Study

Look at individuals with high levels of Cryptosporidium antibodies in regards to:

- water contamination indicators,
- diarrheal and gastro-intestinal illness,
- risk factors for Cryptosporidium infection.
2008-09 Study – Phase 2

- 7 well water samples – once every other month.
- 5 blood samples – once every 3 months.
- 5 questionnaires – once every 3 months.

<table>
<thead>
<tr>
<th>Enrollment</th>
<th>Month Following Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Blood</td>
<td>x</td>
</tr>
<tr>
<td>Questionnaire</td>
<td>x</td>
</tr>
</tbody>
</table>
2008-09 Participants

- Recruitment pool: Phase I participants who had a septic system and well, and who had a serological response ≥20% of the positive control.
- 60 participants selected from exposed group of Phase I.
2008-09 Well Test Results

• In a 13 month cycle, 80% of the wells had microbiological contamination at some point.

• It was common for samples to have multiple microbiological detections, and for wells to test positive more than once.
<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Percentage giving variable answers out of 5 questionnaires</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diarrhea in the last 2 months</td>
<td>35.6 %</td>
</tr>
<tr>
<td>Episodes of GI illness in past year</td>
<td>40.7 %</td>
</tr>
<tr>
<td>Used daycare for child in home</td>
<td>8.5 %</td>
</tr>
<tr>
<td>Handled child in diapers</td>
<td>20.3 %</td>
</tr>
<tr>
<td>Cared for someone with diarrhea</td>
<td>25.4 %</td>
</tr>
<tr>
<td>Visited someone in the hospital</td>
<td>57.6 %</td>
</tr>
<tr>
<td>Handled pets</td>
<td>15.3 %</td>
</tr>
<tr>
<td>Handled young pets</td>
<td>35.6 %</td>
</tr>
<tr>
<td>Handled livestock or wild animals</td>
<td>13.6 %</td>
</tr>
<tr>
<td>Drank untreated water</td>
<td>1.7 %</td>
</tr>
<tr>
<td>Swam or waded in lake or stream</td>
<td>18.6 %</td>
</tr>
<tr>
<td>Used pool, hot tub or water park</td>
<td>35.6 %</td>
</tr>
<tr>
<td>Plumbing work done in home</td>
<td>39.0 %</td>
</tr>
<tr>
<td>Traveled outside United States</td>
<td>37.2 %</td>
</tr>
<tr>
<td>Have pets in home</td>
<td>8.5 %</td>
</tr>
<tr>
<td>Diagnosed with Hepatitis A</td>
<td>3.4 %</td>
</tr>
<tr>
<td>Vaccinated for Hepatitis A</td>
<td>15.3 %</td>
</tr>
<tr>
<td>Eat fresh food or vegetables</td>
<td>8.5 %</td>
</tr>
<tr>
<td>Eat organic vegetables</td>
<td>54.2 %</td>
</tr>
<tr>
<td>Wash produce before eating</td>
<td>35.6 %</td>
</tr>
<tr>
<td>Eat fruit and vegetable peels</td>
<td>79.7 %</td>
</tr>
<tr>
<td>Eat outer leaves</td>
<td>57.6 %</td>
</tr>
</tbody>
</table>
2008-09 Study – Results

Relationship between 27-kDa antibody level ≥ 75% of positive control and a positive water test for total coliforms

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>Adjusted odds ratio and 95% confidence interval</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive total coliform test</td>
<td>59</td>
<td>2.5 (0.7-8.5)</td>
<td>0.14</td>
</tr>
<tr>
<td>Traveled outside the US</td>
<td>59</td>
<td>.18 (0.0-0.8)</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Relationship between 27-kDa antibody level ≥ 75% of positive control and a positive water test for *E. coli* (risk factor: most often positive)

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>Adjusted odds ratio and 95% confidence interval</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive <em>E. coli</em> test</td>
<td>59</td>
<td>2.9 (.96-8.7)</td>
<td>0.06</td>
</tr>
</tbody>
</table>
2008-09 Discussion

• Despite the high number of contaminated well-water samples, there were no associations between positive water tests and diarrhea or GI illness.
• Protective immunity may be occurring.
• Visitors may be susceptible to illness or deposit foreign bacteria, virus or parasite into the septic tank.
2008-09 Conclusions

• Study results suggest an association between contaminated water and infection from *Cryptosporidium.*

• After controlling for other risk factors, the most likely source of exposure is the underground septic system that exists in close proximity to the private wells.

• Having an on-site septic system and well may increase risk of *Cryptosporidium* infection.
• UNM has tracer studies underway using wells and septics from some of the participants of the *Cryptosporidium* study.
Groundwater Nitrate Pollution from Septic Systems

Nitrate mg/L as N

Ground-Water Flow
### Possible Infant Methemoglobinemia (MHG) Cases from Nitrate in Well Water in N.M.

<table>
<thead>
<tr>
<th>Date</th>
<th>Location</th>
<th>$NO_3^-$-N (mg/L) In Well Water</th>
<th>Potential Nitrate Sources</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960’s-70’s</td>
<td>Blue Water</td>
<td>unknown</td>
<td>Uranium mill tailings, septic systems</td>
<td>anecdotal</td>
</tr>
<tr>
<td>1960’s-70’s</td>
<td>Carlsbad</td>
<td>unknown</td>
<td>Septic systems</td>
<td>anecdotal</td>
</tr>
<tr>
<td>1961</td>
<td>Carnuel</td>
<td>132</td>
<td>Septic systems, black powder, marine rocks</td>
<td>Male infant recovered after hospitalization for MHG</td>
</tr>
<tr>
<td>1980</td>
<td>Albuquerque</td>
<td>47</td>
<td>Fertilizers, ET, septic systems</td>
<td>Male infant (5.5 mo. old) recovered after methylene blue treatment; 14.9% methemoglobin in blood</td>
</tr>
<tr>
<td>1996</td>
<td>Veguita</td>
<td>150-200</td>
<td>Fertilizers, ET, septic systems, dairy waste</td>
<td>Female infant (4 mo. old) died of cyanosis, post-mortem methemoglobin blood tests inconclusive</td>
</tr>
</tbody>
</table>

Of the 278+ cases of infant MHG reported by Walton (1951), none were in New Mexico. Infant MHG became a notifiable condition in the State of New Mexico in 2006.
Observations Regarding MHG

- At least 713 private domestic wells in N.M. are known to have been contaminated with high nitrate originating, at least in part, from onsite wastewater systems.
- I have personally visited 7 households where infants were ingesting well water with high nitrate (up to 105 mg/L as N), typically via baby formula or oatmeal, without developing visible symptoms of MHG.
- Blood samples drawn from 3 children at two such households contained normal levels of methemoglobin.
Observations Regarding MHG

- It has long been observed that gastrointestinal illness may be a risk factor in the development of MHG from high nitrate in drinking water.

  - “...methemoglobinemia may occur in an infant following ingestion of water high in nitrates, especially if the infant is suffering from gastrointestinal disturbances.” Walton (1951)

  - “An association between methemoglobinemia and acute gastroenteritis in infants has been noted in several studies and may be due to acidosis from stool bicarbonate loss impairing the already immature function of the methemoglobin reductase system in these young patients.” (Verive, 2011)
Conclusions Regarding MHG

- MHG is a rare health condition in N.M.
- MHG, when it occurs, has caused life-threatening conditions that require emergency medical attention.
Free Well Water Testing

The New Mexico Environment Department has, for 30 years, provided free nitrate tests to people who utilize private domestic wells.

Shannon and Aiden McQuillan measure specific conductance at a Water Fair in Pojoaque, NM, 2004.
References


References, Contd.

- N.M. Administrative Code, § 7.4.3.12, Notifiable Diseases or Conditions in New Mexico, http://www.health.state.nm.us/erd/healthdata/pdf/Notifiable%20DC%20043009.pdf
- N.M. Water Quality Control Commission, 1988 to present, Clean Water Act, §305(b) reports to Congress, http://www.nmenv.state.nm.us/swqb/303d-305b/
Questions?