

# Viruses in Groundwater: From Disease Outbreaks to Sporadic Illness

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#### **Groundwater Virus Studies in Wisconsin**

Environ. Sci. Technol. 2010, 44, 7956-7963

#### Assessment of Sewer Source Contamination of Drinking Water Wells Using Tracers and Human Enteric Viruses

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#### Sand/gravel sandstone aquifers

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Human Enteric Viruses in Groundwater from a Confined Bedrock Aquifer

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Even in a confined aquifer

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#### Incidence of Enteric Viruses in Groundwater from Household Wells in Wisconsin

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domestic

wells

Vulnerability of Drinking-Water Wells in La Crosse, Wisconsin, to Enteric-Virus Contamination from Surface Water Contributions

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#### Municipal wells in an alluvial aquifer



Case Study/

#### Norovirus Outbreak Caused by a New Septic System in a Dolomite Aquifer

by Mark A. Borchardt<sup>1</sup>, Kenneth R. Bradbury<sup>2</sup>, E. Calvin Alexander Jr.<sup>3</sup>, Rhonda J. Kolberg<sup>4</sup>, Scott C. Alexander<sup>3</sup>, John R. Archer<sup>5</sup>, Laurel A. Braatz<sup>6</sup>, Brian M. Forest<sup>7</sup>, Jeffrey A. Green<sup>8</sup>, and Susan K. Spencer<sup>9</sup>

#### **Door County restaurant well**

Vol. 69, No. 2 Private



## Virus Sources and Infiltration Routes into Groundwater



Modified from Keswick and Gerba 1980



## **Health Risk or Non-Issue?**

- So viruses are present in public water supply and domestic wells ...
- Does it matter?
- Is there any effect on public health?





# **Study Objectives**

- Find the association between tap water virus concentrations and community rates of acute gastrointestinal illness (AGI)
   Dublished in Environmental Lealth Decentrations 2012
- Published in Environmental Health Perspectives 2012
- 2) Estimate AGI risk from drinking non-disinfected municipal water from groundwater sources
- Manuscript in preparation
- 3) Estimate AGI risk from viruses directly entering and contaminating distribution systems without residual chlorine
- Published in Environmental Science & Technology 2012
- 4) Find the association between viruses in distribution systems and utility O & M procedures
- Published in Journal of Water and Health 2011



## WAHTER Study Participating Communities

Wisconsin WAHTER Study



Populations: 1,200 – 8,300 Number Wells: 2 – 5 Pumpage: 0.13 – 2.1 MGD Hydrogeology: sand, sandstone, limestone No surface water influence No disinfection



# **Tap Water Sampling**

- Goal was to characterize virus exposure in a community's drinking water
- Sampled 5 to 8 household taps per community; every community sampled once per month
- Households selected using utility-provided maps of water mains



- Viruses captured by glass wool filtration
- Viruses analyzed by qPCR
- In addition, enteroviruses and adenoviruses analyzed by cell culture



#### Virus Types, Frequencies, and Concentrations in Tap Water

	Number qPCR Positive Samples	Virus Concentration Genomic copies/L		Number Culture
Virus Type		Mean	Maximum	Positive Samples
Adenovirus	157 (13%)	0.07	9.5	40/157 (25%)
Enterovirus	109 (9%)	0.8	851.1	31/109 (28%)
GI Norovirus	51 (4%)	0.6	115.7	
GII Norovirus	0 (0%)	0	0	
Hepatitis A	10 (1%)	0.006	4.1	
Rotavirus	1 (0.1%)	2 x 10⁻⁵	0.03	
All Viruses	287 (24%)	1.5	853.6	

**N** = 1,204 samples

> 41 samples (3%) were positive for two or more virus types



# **Epidemiological Study Design**

- Acute gastrointestinal illness (AGI) surveillance for four
  12 week periods, spring and autumn 2006 and 2007
- Participants submitted an illness symptom checklist every week
- AGI defined as ≥ three episodes loose watery stools OR
  ≥ one episode vomiting in 24 hour period
- Person-time estimated from nights slept away from home, self-reported on symptom checklist
- Outcome measure: Number AGI episodes/person-year for each community and surveillance period



# Participating Households' Characteristics

Characteristic	Number	%		
Household size (no. of persons)				
2	17	(3)		
3	159	(26)		
4	246	(40)		
5	136	(22)		
<u>≥</u> 6	63	(10)		
Residence type				
Single family home	572	(92)		
Apartment or condo	43	(7)		
Other	6	(1)		
Faucet or plumbing filtering device				
Yes	73	(12)		
Νο	547	(88)		
Don't know	1	(<1)		
Primary drinking water source				
Municipal	1546	(93)		
Bottled water	58	(3)		
Other	1	(<1)		
Missing	54	(3)		

- Beginning enrollment:
  621 households
- Ending enrollment: 440 households
  - Beginning enrollment: 1,079 children, 580 adults
- Ending enrollment: 765 children, 413 adults



## G1 Norovirus Concentration in Tap Water and AGI Incidence



Wisconsin WAHTER



### Proportion of G1 Norovirus-Positive Tap Water Samples and AGI Incidence



Wisconsin WAHTER



# Maximum G1 Norovirus Concentration and AGI Incidence

AGI Incidence (episodes/person-yr) P = 0.001120 30 40 10 50 0 **Maximum GI Norovirus Concentration** 

Wisconsin WAHTE



### AGI Relative Risk (RR) as Related to the Proportion of Tap Water Samples Positive for G1 Norovirus



Wisconsin WAHTER



# **Results Summary**

Virus Group	Predictor Variables	Age Group Most Affected	Maximum Increase in Relative Risk
All viruses combined	Mean Concentration Maximum Concentration	Adults	105%
Enterovirus	Mean Concentration Maximum Concentration Proportion samples +	Adults	84%
G1 Norovirus	Mean Concentration Maximum Concentration Proportion samples +	All ages	161%

#### Estimating the Fraction of AGI from Drinking Water Using Quantitative Microbial Risk Assessment



- Virus exposure AGI model: mean concentration GI norovirus, all ages
- 22% of the AGI in the study communities was from virus-contaminated tap water
- For children < 5 yrs, in the spring of 2006, the fraction of AGI from drinking water was 63%!



## Does Groundwater-borne Illness Risk Meet US EPA Standards?

- Acceptable EPA risk for waterborne disease is 1 infection in 10,000 people/year
- Assume every infection leads to an illness, then the acceptable illness rate is 0.0001 illness/person-year
- Our modeling using quantitative microbial risk assessment indicates norovirus in drinking water was responsible 0.45 AGI episodes/person-year
- 4,500 times higher than EPA acceptable risk

## Norovirus Outbreak Caused by a New Septic System in a Dolomite Aquifer

ground

Case Study/

by Mark A. Borchardt<sup>1</sup>, Kenneth R. Bradbury<sup>2</sup>, E. Calvin Alexander Jr.<sup>3</sup>, Rhonda J. Kolberg<sup>4</sup>, Scott C. Alexander<sup>3</sup>, John R. Archer<sup>5</sup>, Laurel A. Braatz<sup>6</sup>, Brian M. Forest<sup>7</sup>, Jeffrey A. Green<sup>8</sup>, and Susan K. Spencer<sup>9</sup>



#### **Outbreak Background**

- In early June, 2007, 229 patrons and employees of a new restaurant in Door County were affected by severe acute gastrointestinal illness, 6 people hospitalized
- New well and conventional drain-field septic system, both conforming to State code
- Hydrogeologic setting: shallow soil over densely fractured dolomite
- Epidemiologic case-control analysis indicated the restaurant's well water was associated with illness





Tap water from well: 50 genomic copies/L

Norovirus isolates from 3 sources had identical 327 bp polymerase gene sequences





Restaurant patrons: 10<sup>4 –</sup> 10<sup>8</sup> gc/gm stool

Septic tank: 79,600 genomic copies/L

#### **Restaurant - As Built Septic System and Well**



# Tracer concentrations in the restaurant supply well



# **Restaurant Cross Section**





# Regional Scale Movement of Dye from the Restaurant

Tracer velocities to offsite wells B and D are in the range of 7 to 8 m/d.

# Local Geology Is Illness Factor

### 'Summer Flu' Study Is Made By Scientists

Limestone Fissures Let Wastes Set Into Wells-Say the Researchers

Door county's geology is to blame for so - called "resort diarrhea" according to a U. S. Public Health Service team which, theroughly investigated the fitness last summer. The study was made at the request of the Ephraim Men's club, which heard the preliminary report Thursday night. The report stated that purification of water through chlorination is the practical answer.

Door county is a sliver of top-

#### Not Only Here.

It was pointed out that the problem is not peculiar to Door county but decurs in many other plages where a concentrated population uses well water.

Three officials were here to give the report, Don Mackel, bacisciologist. Norman Feterson suffary engineer, and the Tree Payne. All work out of the USPHS main office at Atlanta, Ga.

More than 200 people cooperated in making the study this summer. There were 10 medical technologists and 200 college students who were working at the resorts.

Soveral factors were checked and it was found that diarrhea cases coincided with periods of

bad water. The degree of sickness depended on the degree of pollution and the amount of water drunk. The number of people in the area had a direct bearing on the amount of pollution. Another factor was rainfall. Bain dilutes the wastes, decreasing pollution.

Doosn't Make Bad Taste

Twenty-nine wells and 22 resorts were tested. Sixty-four per cent showed bad water at some time during the summer. Even the bast constructed well cen

#### 1955!

Article in the Door County Advocate

Policy "Lapse" WI Septic System Code Comm 83 allows 24" minimum distance between drainfield and groundwater table or bedrock, regardless of bedrock type.

#### Groundwater-borne Outbreaks in Karst, USA

http://water.usgs.gov/ogw/karst/kig2002/jbe\_map.html P. Berger (2008), table 1

# Questions? Comments?









