MICROBIAL CONTAMINATION OF GROUNDWATER IN THE PINETOP-LAKESIDE AREA OF NORTHERN ARIZONA

Carl Mohrbacher, Ricardo DeLeon, Gary A. Toranzos, Rebecca L. Mullinax, and Charles P. Gerba (University of Arizona, Tucson, Arizona)

The Pinetop-Lakeside area located in southeastern Navajo County, Arizona, has experienced several outbreaks of probable waterborne gastroenteritis. The many on-lot sewage disposal systems, thin soils and fractured crystalline rock aquifers make this area especially vulnerable to biological degradation of the groundwater supply. This study was designed to assess the extent of bacteriological and virological contamination of groundwater and relationships between indicator bacteria, coliphages and human pathogenic viruses. Twenty different wells were selected and monitored for coliforms, fecal coliforms, fecal streptococci, coliphages, enteric viruses, and various physical and chemical properties of the water. Extensive microbial contamination of the groundwater was observed, which increased dramatically after a period of heavy rainfall. Almost 90% of all well samples contained coiform levels in excess of drinking water standards.

Introduction

The Pinetop-Lakeside area of the White Mountains of Arizona has experienced occasional outbreaks of gastroenteritis during the summer vacation period. The Arizona Bureau of Water Quality control conducted a well-sampling project to determine the extent of bacterial contamination. Although the report has not been published, the results show moderate to high bacterial contamination in about half the wells.

An objective of this study was to determine the extent of microbial contamination of ground water in the Lakeside-Pinetop area. Also, this study was to determine if correlations exist between the presence of microbial indicators and other physical and chemical properties of ground water.

Materials and Methods

A total of 20 wells were sampled on 3 weekends during September and October of 1983. (Table I) Nine wells were sampled on 2 separate weekends and one well was sampled all 3 times (Table II). The second sampling trip, Oct. 1,2 was conducted toward the end of an intense 5-day rainstorm, which produced floods in many parts of Arizona. The other 2 trips occurred during dry weather.
A total of 30 samples were collected for enteric virus assay. Except for #10 and #20, all samples were taken directly from the pumping well rather than from a holding tank. Approximately 100 gallons were pumped through positively charged 293-mm diameter Zetaplus 30S of 50S filters. The absorbed viruses were eluted from the filter with 500ml of 3% beef extract, pH 9.5. The virus samples were further concentrated in the laboratory by flocculation with FeCl₃ and a pH of 3.5. The viruses were resuspended in 30 ml of 0.5 M Na₂HPO₄ and frozen. The enteric virus assays are not complete at this time.

The well water was assayed for bacteria using the membrane filtration technique according to Standard Methods for the Examination of Water and Wastewater (APHA, 1976). Total coliforms, fecal coliforms, and fecal streptococci were enumerated.

Samples for bacteriophages were collected in 50 ml nalgene containers and stored on ice while in the field. For the samples collected during October, the concentrated sample was also assayed for coliphages. Culture and assay methods were similar to those described by Adams (1959).

Other parameters measured were temperature, pH, turbidity, nitrate, ammonia, iron, calcium hardness and total hardness. Hach portable field instruments (Hach Chemical Co., Ames, Iowa) were used to analyze the water for the chemical parameters. Nitrate, ammonia, and iron involved colorimetric procedures, and hardness was determined by titration. Turbidity was measured in the lab with a Hach turbimeter. All Hach procedures are according to APHA Standard Methods. The pH was measured with a probe and a meter which gave 0.1 pH units precision.

Results and Discussion

The relatively low temperatures, average=11.6°C, standard deviation=1.3°C, and moderately low pH, average=6.8, standard deviation=0.6, indicated that the ground water had been recharged recently (Table II). The ground water was moderately hard, average=87 mg/l, standard deviation 49 mg/l. The nitrate concentration was moderately high, average=9.9 mg/l, standard deviation=7.5 mg/l.

Table III shows the results of bacteria and coliphage assays. Total coliforms ranged from 0 to 23,400 /100ml. Fecal coliforms ranged from 0 to 1,360 /100ml and fecal streptococci ranged from 0 to 2,320/100ml. The results of coliphage assays are also shown in Table III. Coliphages ranged from 0 to 57 pfu/ml per 100 gal in the concentrated samples.
Figure 1 is a graph of total coliforms, fecal coliforms, and fecal streptococci, respectively, vs. time for the one well sampled 3 times. All three indicator bacteria had the highest levels in the sample collected during the rainstorm. Wells #12, 13, 14, 17, and 18 were sampled during both a dry weekend and the rainy weekend. In every case, when these indicator bacteria were detected, the highest values occurred during the rainstorm (Table III). These high values probably were caused by the filtration of rainwater which mobilized bacteria in the soil and septic tanks. For wells #12, 14, 17 and 18, the fecal streptococci levels were 1 to 3 orders of magnitude higher during the rainstorm. The susceptibility of the aquifer to large influxes of bacteria is probably due to the following factors: shallow depth to water, shallow soil and weathered-rock zone, and a fractured basalt aquifer with a low primary permeability.

Table IV shows the results of linear regression analysis among the various physical, chemical and microbiological parameters. The negative correlation between temperature and total coliforms, \( R = -0.60 \), is probably due to the well-documented decrease in survival rate of bacteria and viruses with increasing temperature (Bitton, 1980). Similarly, total coliforms decreased with increasing pH, \( R = -0.59 \). Turbidity had a modest positive correlation with fecal streptococci, \( R = 0.41 \). This relationship may be due to the greater survival rate of fecal streptococci relative to the other indicator bacteria, being further enhanced by absorption to suspended solids.

The correlation between coliphage levels in the unconcentrated and concentrated samples was modest, \( R = 0.56 \) (Table IV). In seven of the pairs, coliphage was detected in the concentrated sample but not in the unconcentrated sample.

The coliphage content of the concentrated samples did not show a significant correlation with any of the physical or chemical parameters. However, coliphage was significantly correlated with fecal coliforms, \( R = 0.59 \) and to a lesser extent with fecal streptococci, \( R = 0.49 \).

Conclusions

Several of the phenomena observed in this study have been well documented by other researchers, eg. increased bacteria in shallow aquifers during and after a heavy rainfall, decreases in bacteria survival with increasing temperature and pH. This study has demonstrated that coliphage is present with the bacteria in the groundwater but that the concentrations are near the detection limit.
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<td>25</td>
<td>1</td>
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<tr>
<td>19</td>
<td>23</td>
<td>1</td>
<td>8</td>
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<td>0</td>
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<td>0</td>
<td>0</td>
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</tr>
</tbody>
</table>

nd = not done
Figure 1. Indicator Bacteria for Well 4
### TABLE IV

**R Values from Linear Regression Analysis**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Total Coliforms</th>
<th>Fecal Coliforms</th>
<th>Fecal Streptococci</th>
<th>Coliphage/Concentrated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Coliforms</td>
<td>1.00</td>
<td>-0.14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fecal Coliforms</td>
<td>0.10</td>
<td>1.00</td>
<td></td>
<td>0.59</td>
</tr>
<tr>
<td>Fecal Streptococci</td>
<td>0.37</td>
<td>0.54</td>
<td>1.00</td>
<td>0.49</td>
</tr>
<tr>
<td>Temperature</td>
<td>-0.60</td>
<td>-0.36</td>
<td>-0.33</td>
<td>-0.24</td>
</tr>
<tr>
<td>pH</td>
<td>-0.59</td>
<td>-0.31</td>
<td>-0.48</td>
<td>-0.33</td>
</tr>
<tr>
<td>Nitrate</td>
<td>0.26</td>
<td>0.23</td>
<td>0.23</td>
<td>0.29</td>
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<td>Ammonia</td>
<td>-0.03</td>
<td>-0.00</td>
<td>0.14</td>
<td>0.10</td>
</tr>
<tr>
<td>Iron</td>
<td>0.08</td>
<td>-0.14</td>
<td>0.00</td>
<td>-0.37</td>
</tr>
<tr>
<td>Total Hardness</td>
<td>0.23</td>
<td>0.04</td>
<td>-0.03</td>
<td>-0.37</td>
</tr>
<tr>
<td>Turbidity</td>
<td>0.03</td>
<td>0.19</td>
<td>0.41</td>
<td>0.12</td>
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<td>Coliphage/Direct</td>
<td>-0.00</td>
<td>0.31</td>
<td>0.69</td>
<td>0.56</td>
</tr>
</tbody>
</table>

--- underline means the correlation coefficient, R, is significant at the 0.05 level.

### References Cited

