ASSESSMENT OF HEALTH RISKS

ASSOCIATED WITH VIRUSES IN GROUNDWATER SUPPLIES

PIERRE PAYMENT, CENTRE INRS-INSTITUT ARMAND FRAPPIER

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Canadian Water Network

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WHY DID WE DO THIS RESEARCH?

Knowledge about the occurrence of microbial contaminants in groundwater is essential when assessing public health risks. Between 1974 and 2001, human enteric viruses (primarily Norwalk and Hepatitis A) were responsible for at least 24 public health outbreaks in Canada. There are a large number of Canadian municipalities that rely on groundwater as their source of drinking water. If these sources are contaminated by viruses, waterborne outbreaks can result.

Groundwater is generally safer than surface water as a source of drinking water due to natural filtration and a recharge time-delay from contaminant sources. However, human enteric viruses may still occur in groundwater if the right conditions exist – for example, when groundwater is under the direct influence of surface water.

There are currently no reliable direct indicators for measuring enteric viruses in groundwater. Bacterial monitoring (using indicators such as total coliforms and E. coli, enterococci and coliphages) is used as a surrogate for viral detection. However, water sources that are free of these fecal microorganisms can still contain viruses that can put people's health at risk.

To better understand raw source water quality, testing for both viruses and their bacterial indicators is needed in order to properly assess the success rate of those indicators.

Testing for viruses in water and evaluating the risks they pose is challenging, since as few as one virus can infect a human. Because viruses in a water sample may be scarce, they must be concentrated from hundreds of litres of water in order to increase the chance of detection. With groundwater, the sample size needed is as large as over 1000 litres. There is limited Canadian data available, because few laboratories are able to perform these tests.

The objectives of this study were:

- To measure the occurrence of viruses in untreated groundwater sources from selected communities in Canada, and assess their risk to public health.
- To determine whether current microbial testing is adequate to monitor virus occurrence in groundwater.
- To investigate the advantage of using other microbial indicators as virus surrogates.

A team of experts in the fields of microbiology, hydrology, hydrogeology, civil engineering and public health, with representatives from Ministries of the Environment and Health from Québec, Ontario and Alberta, conducted this research.

WHAT DID WE DO?

Groundwater from municipal wells in three provinces was tested for the presence of human enteric viruses and a suite of bacterial indicators over one year. To obtain representative sites, site selection was done in collaboration with Ministries of the Environment from Alberta, Ontario and Québec. Wells from 35 municipalities were selected. Each site was located in an area with human activity and had historic data of raw water quality.

The sites were categorized into two groups:

- clean sites with little bacterial contamination, or
- contaminated sites with a history of bacterial indicators

Water managers and operators were contacted and asked to complete a detailed questionnaire in addition to providing samples from one of their wells. Sampling kits were assembled for on-site use that included a virus-adsorbing filter (Figure 1). In order to increase the sensitivity of the tests for the detection of viruses, new molecular methods were used for detecting viruses in the samples. These methods permit the detection of viruses that do not grow in the cell cultures used for their detection.

Figure 1. Virus concentration apparatus

A total of 167 samples were obtained for virus and for bacterial testing:

INDICATORS ASSESSED	CONTAMINANT	RATIONALE FOR SAMPLING IN THIS RESEARCH
TOTAL COLIFORMS	Bacteria	Current regulatory standard
E. COLI	Bacteria	Current regulatory standard
ENTEROCOCCI	Bacteria	Current regulatory standard in some provinces
COLIPHAGES	Viruses	Viruses of coliform bacteria that behave like human enteric viruses in groundwater
AEROBIC ENDOSPORES	Bacteria	Common bacteria that suggest surface water contamination

Table 1. Viruses and bacterial indicators used in sampling and the rationale for using each

All results collected were analysed to evaluate the relationships between the presence of viruses and various indicators, including rainfall events and possible groundwater flows.

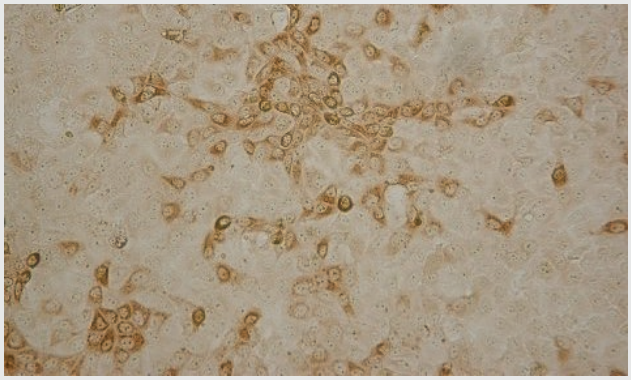
WHAT DID WE FIND?

- Total coliforms were barely detected in five samples from clean sites, but more often and at higher levels from the contaminated sites.
- E. coli was not found at any of the clean sites, but was found at low levels at two sites which had been categorized as contaminated.
- Enterococci were detected once at a clean site and once at a contaminated site.
- Coliphages were not detected at any of the clean sites, but were detected more frequently at the contaminated sites.
- Aerobic endospores were barely detected in samples at the clean sites. They were detected more frequently and at higher concentration at the two contaminated sites.
- 130 samples were analysed for the presence of human enteric viruses by cell culture. Only one site tested positive.
- All samples analyzed by molecular methods were negative.

Most of the sites selected for this project were considered to be clean and not vulnerable to contamination. No indicator of fecal pollution was found during the one-year sampling period. The data collected shows that apart from a single sample that tested positive for enterococci at one site, the sites categorized as clean proved to be of excellent quality. These findings confirm previous research findings that clean groundwater sites which are free of bacterial indicators are usually free of viruses. Thus, the value of available historical data to determine the vulnerability of wells remains an essential step in evaluating any groundwater, particularly if it is a drinking water source.

Monitoring enterococci and coliphages did not provide additional information and do not seem worthy of the additional testing costs. The literature suggests that aerobic endospores could be a promising indicator of plant performance, but their use as an indicator of groundwater quality would require further research and laboratory standardization.

The absence of total coliforms and aerobic endospores is suggestive of bacterially clean water. The presence of total coliforms and aerobic endospores would be a clear indicator of degradation of source water quality. Further investigation could be conducted to determine the source of contamination; however, these tests may not warrant regulatory testing and could instead be used as a preventative approach.



Viruses detected in cell culture

The presence of bacterial indicators suggests that contaminated surface water is entering the aquifer, thus implying the potential for viruses to follow. Monitoring the combination of E. coli and total coliforms provides an excellent assessment of potential fecal contamination and related public health risks.

The results shown in Tables A, B, and C support the importance of frequent sampling to detect incoming fecal contamination. Water degradation can occur and disappear rapidly, particularly after rain events. Sampling at exactly the right time is a challenge. Table B shows the effect of spring melt and rains, while Table C shows the effect of autumnal rains. These occurrences would not have been detected with a less frequent sampling program.

MONTH	TOTAL COLIFORMS	E. COLI	VIRUSES
DEC	0	0	ND
JAN	0	0	ND
FEB	0	0	ND
MAR	0	0	ND
APR	0	0	<2
MAY	0	0	<2
MAY	0	0	<2
JUN	0	0	<2
JUL	0	0	<2
AUG	0	0	<2
SEPT	0	0	<2
OCT	0	0	<2
NOV	0	0	<2
DEC	0	0	<2

Table A. Clean site from Quebec

MONTH	TOTAL COLIFORMS	E. COLI	VIRUSES
DEC	5	0	ND
JAN	29	0	ND
FEB	5	0	ND
MAR	28	0	ND
APR	41	0.5	9.2
MAY	0.5	0	<2
MAY	2	0	<2
JUN	0	0	<2
JUL	1	0	<2
AUG	2.5	0	<2
SEPT	0	0	<2
OCT	0	0	<2
NOV	0	0	<2
DEC	0	0	<2

Table B. Vulnerable site from Quebec

MONTH	TOTAL COLIFORMS	E. COLI	VIRUSES
DEC	76	0	ND
JAN	330	0.5	ND
FEB	32	0.5	ND
MAR	955	10	ND
APR	61	0.5	17.2
MAY	21	0.5	<2
MAY	12	0	<2
JUN	29	1	<2
JUL	153	9	<2
AUG	185	4	5
SEPT	500	10	248
OCT	43.5	0	18
NOV	18	0.5	62
DEC	30.5	1	4

Table C. Contaminated site from Quebec

LEGEND	
BACTERIA	VIRUSES
(CFU/100 ML)	(INFECTIOUS UNITS /1000L)
<0,5	<2
0,5-10	41914
11-100	11-100
>100	>100

Tables modified from Locas et al. (2007).

WHAT DO THESE FINDINGS MEAN FOR MUNICIPALITIES?

Climate changes, including more frequent and higher intensity rainfall events, have the potential to alter groundwater quality very rapidly, transporting more pollutants to aquifers from surface contamination. Currently, the frequency of monitoring for bacteriological indicators is low – sometimes a single sample per month. Given the potential transient nature of groundwater, where seasonal conditions and climate events can alter water quality daily, more frequent testing for E. coli and total coliforms is recommended. This information would enable the water provider to react rapidly when changes occur and apply appropriate disinfection treatment.

Available historical data plays an important role in determining the vulnerability of groundwater sources to contamination by bacteria and viruses. Sites with a history of contamination are the most vulnerable to continued contamination. Due to the sparse detectability of viruses through standard sampling methods, larger data sets provide better insight into water quality and potential contamination across the seasonal range and under varied hydrologic conditions. Municipalities should utilize historical raw water quality data available in order to determine which sites offer the safest sources of drinking water.

Monitoring the combination of E. coli and total coliforms provides an excellent assessment of potential fecal contamination and related public health risks.

Monitoring the combination of E. coli and total coliforms provides an excellent assessment of potential fecal contamination and related public health risks. The use of these two indicators is also cost effective due to the existence of a standardized method where simultaneous detection can be determined using the same culture media. Monitoring enterococci and coliphages did not provide additional information and do not seem worthy of the additional testing costs.

Treatment and disinfection of groundwater is now common practice and required in some provinces. It is a safety barrier that will minimize the risks to consumers and the risk of outbreaks. Understanding the need behind treatment and disinfection requirements, the potential for rapid changes in groundwater quality, and the connection between raw water sampling and vulnerability, will better prepare water operators to provide safe drinking water to their communities.

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