Norovirus contamination of a drinking water supply at a hotel resort

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Abstract

**Aim** To investigate a waterborne gastroenteritis outbreak and consider wider environmental contamination concerns.

**Methods** An acute gastroenteritis outbreak was investigated through interviews, analysis of faecal samples, drinking water and environmental water samples.

**Results** A total of 53 cases reported an illness of acute gastroenteritis following stays and/or dining at a hotel or neighbouring resort in southern New Zealand over a 1-month period in early spring 2012. The consumption of table or tap water was strongly associated with the illness. Faecal samples were positive for norovirus (NoV) genogroup I and II (GI and GII). Drinking tap water samples were positive for NoV GI and GII but negative for *Escherichia coli* (*E. coli*). Wider environmental water testing at local drinking water sources, around the sewage disposal field and at the nearby river showed the presence of NoV GI and GII. Voluntary boil water notices were issued and implemented with no further cases following this action. Additional treatment of drinking water supplies has been implemented and sewerage disposal concerns referred to local government.

**Conclusion** Investigation of this gastroenteritis outbreak revealed contamination of both drinking water and the wider environment with NoV. Bacterial indicators do not adequately cover contamination by viruses but due to costs, frequent virus monitoring programmes are currently impractical. A strategy to decrease environmental contamination of drinking water supplies in this busy tourist location through improved management of sewage disposal and drinking water is urgently required.

**Background**—Noroviruses (NoV) are non-enveloped, single-stranded RNA viruses belonging to the *Caliciviridae* family. They have a low infectious dose and similar to other enteric viruses can remain infectious in the environmental waters for long periods, surviving longer than bacteria.1–4 In New Zealand, NoV is the most commonly identified cause of gastroenteritis outbreaks characterised by an acute illness of nausea, vomiting and/or diarrhoea.5 Globally, waterborne NoV outbreaks caused by inadequately treated human wastewater contaminating drinking water supplies are well recognised. Both NoV genogroup I and II (GI and GII) are frequently implicated in waterborne outbreaks associated with drinking and recreational water.1,6–9

Two waterborne NoV outbreaks have been previously described in New Zealand,10,11 both resulting from consumption of contaminated drinking water at two different ski resorts. Other suspected waterborne NoV outbreaks have been reported in New Zealand but not confirmed.
Although city and town drinking water supplies are well regulated and monitored in New Zealand, small community water supplies have until recently been under voluntary regulation. *E. coli* levels are used as the indicator of contamination of water supplies in New Zealand.

On 27 August 2012, Public Health South were notified that 11 people from a group of 15 diners at a hotel close to a ski resort had become ill with gastroenteritis between 24 and 48 hours after dining on 24 August. A foodborne, waterborne, and/or person-to-person outbreak was considered. The group had consumed table water sourced from the hotel kitchen tap.

During the subsequent 2 weeks, there were reports of three groups who reported similar symptoms after dining at the same hotel, staying at the neighbouring resort, or consuming only tap water from the same water supply. Of note, one of these groups was three visitors just passing through the township and had only consumed tap water. Previous sporadic cases of gastroenteritis had been reported from 18 August, including four staff from the hotel. This report describes the outbreak investigation.

**Outbreak setting**—The outbreak setting was a hotel located close to five major ski areas which can cater for groups up to 120, or al fresco dining for 200. It is a popular destination for ‘apres-ski’ refreshment, with several hundred people visiting each day during the ski season. It also offers accommodation with 16 rooms. A neighbouring resort, with an independent water supply and sewage system provides self-contained accommodation and recommends the hotel for dining. A small township surrounds the hotel and resort, and the hotel water system supplies water to neighbouring residences or facilities via 11 water access points.

**Methods**

**Epidemiological investigation**—A retrospective investigation was initiated using a standardised questionnaire via direct or telephone interviews. Initially, attempts were made to contact all who may have been exposed. Due to the resort largely catering for domestic or international tourists, locating and contacting all those who may have been exposed to conduct a cohort study was unsuccessful despite multiple contact attempts. Contacting local households also proved difficult as many dwellings were unoccupied, or were rented out as holiday accommodation with a rapid turnover of guests.

As the outbreak evolved it was decided to focus the questionnaires only on those who were symptomatic. Exposure between 15 August and 15 September was assessed to capture possible secondary cases. A case was defined as any person visiting or living in the township who developed acute gastroenteritis (vomiting and/or diarrhoea) within 12–48 hours of visiting between 15 August and 15 September. Data from the outbreak was entered in EpiData v3.1 and analysed with EpiInfo v3.5.3 software.

**Environmental investigation**—The restaurant and kitchen at the hotel were inspected for hygiene and application of cleaning schedules and the sickness policy for staff. The water system was inspected by the local authority and water engineers. Visual inspection was conducted of the waste water system including the sewage disposal field and water run-off; the drinking water system including the bore site in relation to the disposal fields and run-off, the bore, chlorine pump system, and storage tanks. In addition the neighbouring resort bore site and sewage disposal fields were examined later in the investigation.

The free available chlorine (FAC) levels were determined from the kitchen tap water on the 6 September using a portable chlorine metre (Pocket Chlorimeter™ II, Hach Company, Colorado, USA).

**Microbiological investigation**—Between 29 August and 12 September, eight faecal samples were collected from symptomatic patrons who were still in the region. The samples were referred to
Environmental Science and Research Ltd (ESR) for bacterial pathogens associated with acute gastroenteritis and/or tested for NoV GI and GII as previously described.\textsuperscript{12}

The leftover food sample from a patron in the initial affected group was also collected on 29 August and referred to ESR for bacteriology testing including for \textit{Bacillus cereus}, \textit{Clostridium perfringens}, \textit{Salmonella} spp, and \textit{Campylobacter} spp.

On 6 and 7 September, water samples were collected from the hotel kitchen tap with further water samples collected between 7 and 24 September (Table 1) from the following locations: hotel kitchen tap; hotel bore; neighbouring resort outside tap; neighbouring resort drinking water tap.

Environmental water samples from the local river surface water, and surface water upstream and downstream of sewage disposal fields were also collected on 13 and 14 September. All water samples were tested for total coliforms, \textit{E. coli}, and also submitted to ESR for NoV GI and GII testing. Briefly, viruses were concentrated from water samples (20 L) using ultrafiltration based on previously described methods\textsuperscript{10} with NoV GI and GII detection using two-step real-time reverse transcriptase-PCR (RT-qPCR) assays.\textsuperscript{13,14} The NoV genotype for each sample was determined by sequencing in the NoV polymerase region B and capsid region C.\textsuperscript{12}

**Results**

Direct or telephone interviews were conducted with 66 people. Most of the people interviewed had been ill with acute gastroenteritis. However, some residents whose properties were on the hotel water supply but had not become ill, or reported a gastroenteritis illness before the onset date of this outbreak, were also interviewed early in the investigation.

There were 53 cases that fulfilled the case definition meeting the requirements for dates, symptoms and exposure. The cases had a mean age of 41 years (range 4 to 73 years) with equal numbers of male and female. The mean incubation period was 2.1 days (range 0 to 6 days). However, five cases that occurred from 4 to 6 days following exposure are considered most likely due to person-to-person secondary infection. With these cases excluded, the mean incubation period was 1.7 days.

The mean duration of illness was 36 hours (range 4 to 100 hours). Among the cases were 12 residents of the township whose houses were supplied from the same water supply.

Diarrhoea was reported in 74% (95\% CI, 59–85) of cases; 63\% (95\% CI 48–77) and 66\% (95\% CI 52–79) reported nausea and vomiting respectively; and 22\% (95\% CI 11–36) reported fever. The epidemic curve showing the gastroenteritis cases from 17 August to 5 September is shown in Figure 1.

**Microbiological investigation**—The leftover food was negative for \textit{Bacillus cereus} (<10 CFU/g), \textit{Clostridium perfringens} (<10 CFU/g), \textit{Salmonella} spp (not isolated), and \textit{Campylobacter} spp (not isolated).

Of the eight faecal samples collected, seven were tested for NoV and three tested for bacterial pathogens. Five faecal samples were NoV GI positive and one sample was both NoV GI and NoV GII positive. One sample was NoV negative and insufficient faecal material was submitted from one case. Three samples tested for bacterial pathogens were negative for \textit{Salmonella} spp, \textit{Shigella} spp and \textit{Campylobacter} spp (Table 1).
Water samples from the hotel drinking tap taken on 6 September and from the bore on 13 September were NoV GI positive. Samples taken from the hotel drinking tap were negative for *E. coli* (<1 MPN/100 mL) on 14 September (Table 1).

A water sample from the neighbouring resort outside drinking tap taken on 13 September was NoV GI and GII positive. *E. coli* concentrations from the resort drinking water tap and bore contained were <1 most probable number (MPN)/100 mL and 17 MPN/100 mL respectively during the outbreak period (Table 1).

Environmental water samples from the local river surface and downstream of the resort disposal field collected on 13 and 14 September respectively were both NoV GI and GII positive. *E. coli* concentrations for the river surface and downstream of resort samples were 23 MPN/100 mL and 17 MPN/100 mL respectively on 14 September (Table 1).

Further NoV characterisation showed that NoV GI.7 was identified in three faecal samples. In one of the faecal samples that contained both GI and GII, the GII was identified as the GII.4 Sydney_2012 variant. GII.4 Sydney_2012 variant was also identified in a resort water sample and one environmental water (surface water downstream of disposal field) sample, both taken on 13 September. The NoV GI detected in two of the faecal samples, two drinking water samples and two environment waters and the NoV GII detected in the river surface collected on 13 September were not successfully genotyped.
Table 1. Microbiological investigation results

<table>
<thead>
<tr>
<th>Sample</th>
<th>Date sample taken</th>
<th>Norovirus genogroup I</th>
<th>Norovirus genogroup II</th>
<th>E. coli MPN/100 mL</th>
<th>Bacterial pathogens</th>
<th>FAC levels (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Food</strong></td>
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<tr>
<td>Leftover food from hotel</td>
<td>29/08/12</td>
<td>Negative</td>
<td>Negative</td>
<td></td>
<td>Negative</td>
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<tr>
<td><strong>Faecal samples</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>1</td>
<td>29/08/12</td>
<td>POSITIVE</td>
<td>Negative</td>
<td>Negative</td>
<td>Negative</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>31/08/12</td>
<td>POSITIVE</td>
<td>Negative</td>
<td>Negative</td>
<td>Negative</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>31/08/12</td>
<td>Insufficient sample</td>
<td></td>
<td></td>
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<tr>
<td>4</td>
<td>07/09/12</td>
<td>POSITIVE</td>
<td>Negative</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>5</td>
<td>07/09/12</td>
<td>POSITIVE</td>
<td>Negative</td>
<td></td>
<td></td>
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<tr>
<td>6</td>
<td>11/09/12</td>
<td>Negative</td>
<td>Negative</td>
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<tr>
<td>7</td>
<td>11/09/12</td>
<td>POSITIVE</td>
<td>Negative</td>
<td></td>
<td></td>
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<tr>
<td>8</td>
<td>12/09/12</td>
<td>POSITIVE</td>
<td>POSITIVE</td>
<td></td>
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<td><strong>Drinking water</strong></td>
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<tr>
<td><strong>Hotel water supply</strong></td>
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<tr>
<td>Drinking tap</td>
<td>06/09/12</td>
<td>POSITIVE</td>
<td>Negative</td>
<td>Negative</td>
<td>&lt;0.2</td>
<td></td>
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<tr>
<td>Drinking tap (merchandise store)</td>
<td>13-14/09/12</td>
<td>Negative</td>
<td>Negative</td>
<td>Negative</td>
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<td>Drinking tap (pub)</td>
<td>16/09/12</td>
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<td></td>
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<td>0.56</td>
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<td>Bore</td>
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<td></td>
<td></td>
<td>0.52</td>
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<tr>
<td>Bore (un-chlorinated)</td>
<td>13/09/12</td>
<td>POSITIVE</td>
<td>Negative</td>
<td>Negative</td>
<td></td>
<td></td>
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<tr>
<td>Bore</td>
<td>15/09/12</td>
<td></td>
<td></td>
<td></td>
<td>1.07</td>
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<tr>
<td>Bore</td>
<td>16/09/12</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Water tank</td>
<td>13/09/12</td>
<td>Negative</td>
<td>Negative</td>
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<tr>
<td><strong>Resort water</strong></td>
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<td></td>
<td></td>
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<tr>
<td>Drinking tap (outside)</td>
<td>13-14/09/12</td>
<td>POSITIVE</td>
<td>POSITIVE</td>
<td>17</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Environmental water</strong></td>
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<td></td>
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<td></td>
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</tr>
<tr>
<td>River surface water</td>
<td>13-14/09/12</td>
<td>POSITIVE</td>
<td>POSITIVE</td>
<td>23</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface water upstream of resort disposal field</td>
<td>13-14/09/12</td>
<td>POSITIVE</td>
<td>Negative</td>
<td>31</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface water downstream of resort disposal field</td>
<td>13-14/09/12</td>
<td>POSITIVE</td>
<td>POSITIVE</td>
<td>17</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 E. coli MPN/100 mL: E. coli most probable number per 100 millilitres. For every 100mL of drinking water tested, no total coliforms or E. coli should be detected.

1 FAC mg/L: Free available chlorine. A residual of at least 0.2 mg/L is required for adequately treated drinking water.

**Environmental investigation**—On 6 September, a general inspection of the hotel kitchen was conducted identifying a clean kitchen that had regular and strict cleaning schedules. Since the notification of the initial group they had increased their cleaning and sanitising of all surfaces. The chef was very experienced and meticulous with food preparation.

The hotel manager was also questioned regarding their sickness policy. Sick staff records were entered into the template for a Food Control Plan. However, they did not
follow this sickness policy in this outbreak, with the staff approximate exclusion time of only 24 hours rather than the recommended 48 hours.

The water system comprised a bore from which water was chlorinated and pumped to holding tanks, then flowing by gravity assistance to the hotel and other water access points.

Initial FAC results on 6 September indicated inadequate chlorination (Table 1). The bore for this water supply was situated 70 m downstream from the disposal field for the hotel, and in the drainage path from the resort disposal field, and 45 m away from a private house septic tank. The 14 m deep bore with a water depth of 7.8 m was not completely secure allowing surface water flooding contamination.

The chlorination system was assessed and an airlock was discovered which was resolved and the holding tanks were re-chlorinated. Super-chlorination was not undertaken. Later inspection revealed that the chlorine pump was ineffective in injecting chlorine against the flow of water explaining the low chlorination levels. A new chlorine pump was fitted, and re-chlorination was commenced with frequent testing to ensure adequate chlorination was occurring.

Observation of the neighbouring septic disposal field revealed visible surface water run-off across the valley potentially seeping into the ground water from which the bore drew water.

**Discussion**

This outbreak resulted in acute gastroenteritis of at least 53 people in a busy tourist location. As in most outbreaks, the actual number is likely to be considerably higher and anecdotal reports suggested much higher numbers of cases over that period. This is the third waterborne NoV outbreak caused by sewerage contamination of drinking water documented in New Zealand.\(^{10,11}\)

**Norovirus contamination**—Based on our findings, we believe that there was a link between the contamination of drinking water and reported illness, but acknowledge there were limitations in the study design. NoV GI and GII were detected from faecal samples of cases, from the hotel and resort drinking water taps, the hotel bore water, and the wider environment.

The NoV GI.7 identified in the samples from cases is an uncommon genotype,\(^{12}\) having only been previously identified once in the last 10 years in New Zealand (J Hewitt, unpublished data). Therefore, the identification of this genotype in three of the samples supports the epidemiological investigation.

It is interesting that whilst GII.4 are predominant in institutional outbreaks in New Zealand and overseas,\(^{12,16}\) NoV GI and non-GII.4 are frequently associated with waterborne outbreaks including in the previously documented New Zealand waterborne outbreaks.\(^{10,11}\) Although the NoV GII.4 Sydney_2012 variant also detected in this outbreak was the predominant strain circulating in New Zealand in late 2012,\(^{17}\) its occurrence at the time of the outbreaks (end of August 2012) was unusual. Therefore, its presence in both the faecal samples and the water samples was considered significant.
E. coli concentrations from the river surface water were within the acceptable limits for recreational water. Although water samples taken from the hotel kitchen tap and bore were NoV positive, they were negative for faecal coliforms and E. coli illustrating that in some instances, a positive NoV result can occur despite a negative E. coli result.

**Water and wastewater**—We concluded that problems with hotel water system management and wastewater, and specifically with the groundwater intake separation distance, contributed to this outbreak.

The water management system for the neighbouring resort was also found to be inadequate, with unfiltered, untreated water from a bore that was not totally protected. It was found that the water supply had several positive E. coli results in the previous few months, and at the time of the investigation contained 17 MPN/100 mL E. coli and NoV GI and GII.

In New Zealand, prior to the passing of the Health (Drinking Water) Amendment Act in October 2007, community drinking water supplies were largely unregulated. The Drinking Water legislation has a sequential introduction from 2012 to 2016 depending on the population size served by a water source. It requires each water supply serving more than 500 people to have a Public Health Risk Management Plan (PHRMP) that identifies and manages potential risks to the water supply by 2012 to 2015.

For all water supplies serving 25 or more people, “all practicable steps” must be taken to comply with drinking water standards by 2016. However, the current legislation does not adequately address drinking water and wastewater risk management for small resident populations that have large seasonal influxes due to tourism.

The status, registration and monitoring of the resort water supply was inadequate despite fulfilling legislative requirements for the current time. The initial registration was for single title self-supply but subsequent development and issuing of unit titles should have obligated the registration of the resort water supply as a small community drinking water supply with attendant monitoring recommendations. This was recommended in 2008 but never actioned.

Discharge consent monitoring was however conducted using the resort bore drinking water as a convenient testing point and reported to the regional council. Repeated high E. coli counts were overlooked as they met environmental water standards suitable for discharge despite failing drinking water standards.

New Zealand drinking water quality is monitored by assessing E. coli concentrations as an indicator of water contamination by excrement from humans, birds or animals. New Zealand follows the World Health Organization recommendations that no E. coli should be detected in drinking water. Virological compliance standards have not yet been set for New Zealand although this is planned for future drinking-water standards (Chapter 7). The current recommendation states that ‘In the absence of any minimum acceptable values for viruses in the current DWSNZ it should be understood that if they are specifically sought, they should not be detected’.

Treatment of drinking water depends on the quality of source water. It could include chlorination, filtration and coagulation, ultraviolet treatment or ozone treatment. Ultraviolet disinfection may not provide adequate protection against viruses, and if
treatment does not include filtration, at least two disinfectants should be used to provide adequate protection against viruses as well as protozoa.\textsuperscript{18}

Human faecal contamination of the bore water with NoV is the likely cause of this outbreak. Inspection of the hotel bore site revealed possible reasons for contamination including inadequate bore protection, and being sited downstream of visible runoff from the neighbouring resort disposal field.

Private small community water supplies, whilst requiring initial consents from local government authorities, can currently operate with minimal risk management. The New Zealand Ministry for the Environment’s National Environmental Standard for Sources of Human Drinking-water requires that regional councils ensure that effects on drinking-water sources are considered in council decisions on resource consents and regional plans.

ESR has recommended separation distances between wastewater discharges and groundwater intakes to reduce the likelihood of contamination based on viral transport rather than the more commonly used bacterial transport.\textsuperscript{20} Using the ESR recommendations we calculated that the minimum separation distance between sewage disposal field and bore for this hotel and resort should have been about 300 m.

Viruses can survive for long distances in aquifers,\textsuperscript{9} and can have low infectious doses.\textsuperscript{4} Some Regional Councils have set separation distances based on bacterial transport, or have no specified requirements. This should no longer be acceptable in New Zealand.

Fragmented approaches to small community drinking water and sewerage infrastructure and consenting processes lead to unclear responsibilities for private owners, local and regional councils. The current approach to rural subdivision by local government, under the Resource Management Act can result in piecemeal private development, which in this case, has permitted drinking water sources and wastewater disposal to co-exist in close proximity to each other. Despite existing legislation including the Health Act, Building Act and Drinking Water Standards these outbreaks due to contaminated drinking water can and do occur in NZ.

\section*{Conclusion}

Investigation of this gastroenteritis outbreak revealed drinking water and wider environmental contamination with NoV. A strategy to decrease environmental contamination of drinking water supplies in this busy tourist location through improved management of sewage disposal and drinking water is urgently required. Bacterial indicators may not adequately cover contamination by viruses, however due to costs and specialised tests required, frequent virus monitoring programmes are currently impractical.

All local government should take note of this outbreak and consider mitigating risks through a comprehensive adherence to recommended separation distances between drinking water sources and sewerage disposal systems.

\textbf{Competing interests:} Nil.

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