How much of an issue is microbial contamination of our water? 
What’s the sources of contamination of our water? 
How are we trying to keep our water safe for drinking and recreation?

Brent Gilpin 
brent.gilpin@esr.cri.nz 
11 December 2019
### Waterborne Pathogens

#### Viruses
- Norovirus
- Enteroviruses
  - Polioviruses, Echoviruses
  - Coxsackieviruses A & B
- Hepatitis A & E Viruses
- Adenoviruses
- Reoviruses
- Rotaviruses
- Caliciviruses
- Astroviruses
- Picornavirus/parvoviruses
- Coronaviruses

#### Bacteria
- Salmonellae
- Shigella spp.
- Campylobacter spp.
- Yersinia enterocolytica
- Escherichia coli
- Vibrio cholerae
- Aeromonas spp.
- Helicobacter pylori
- Legionellosis
- Leptospirosis

#### Protozoa
- Giardia intestinalis
- Cryptosporidium parvum
- Entamoeba histolytica
- Toxoplasma gondii
- Microsporidia
- Naegleria fowleri
HOW MUCH OF AN ISSUE IS MICROBIAL CONTAMINATION OF OUR WATER?
**Recreational Water and Infection: A Review of Recent Findings**

**Lorna Fewtrell · David Kay**

<table>
<thead>
<tr>
<th>Study</th>
<th>Area</th>
<th>Water type</th>
<th>Participants</th>
<th>Risk of GI illness (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dorevitch (CHEERS)</td>
<td>Chicago</td>
<td>Freshwater</td>
<td>10,747</td>
<td>1.46 (1.08-1.96)</td>
</tr>
<tr>
<td>Marion</td>
<td>Ohio</td>
<td>Freshwater</td>
<td>965</td>
<td>3.2 (1.1-9.0)</td>
</tr>
<tr>
<td>Arnold</td>
<td>California</td>
<td>Marine</td>
<td>5,454</td>
<td>1.9 (1.17-3.06)</td>
</tr>
<tr>
<td>Colford</td>
<td>California</td>
<td>Marine</td>
<td>9,525</td>
<td>1.38 (1.03-1.86)</td>
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<tr>
<td>Papastergiou</td>
<td>Greece</td>
<td>Marine</td>
<td>4,367</td>
<td>3.6 (1.28-10.13)</td>
</tr>
<tr>
<td>Harder-Lauridsen</td>
<td>Copenhagen</td>
<td>Marine</td>
<td>838</td>
<td>5.0 (4.0-6.39)</td>
</tr>
<tr>
<td>Wade (NEEAR)</td>
<td>USA</td>
<td>Marine</td>
<td>6,331</td>
<td>2.56 (1.29-5.11)</td>
</tr>
</tbody>
</table>
2012 Hampton Court Swim

2.25 miles river swim in Thames River
Hampton Court Bridge downstream to Kingston Bridge

1,100 swimmers
1 hospitalised
Facebook page 40 swimmers reported illness
636 valid surveys, 338 illness
Attack rate >31%

Sewage overflow?
Gastrointestinal virus?

**Estimate of incidence and cost of recreational waterborne illness on United States surface waters**

Stephanie DeFlorio-Barker\(^1\), Coady Wing\(^2\), Rachael M. Jones\(^1\) and Samuel Dorevitch\(^1,3\)

<table>
<thead>
<tr>
<th></th>
<th>USA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>329,245,000</td>
</tr>
<tr>
<td>Recreation Events</td>
<td>4 billion</td>
</tr>
<tr>
<td>Annual illness</td>
<td>90 million</td>
</tr>
<tr>
<td>Costs</td>
<td>US$3 billion</td>
</tr>
</tbody>
</table>
Estimate of incidence and cost of recreational waterborne illness on United States surface waters

Stephanie DeFlorio-Barker\textsuperscript{1\ast}, Coady Wing\textsuperscript{2}, Rachael M. Jones\textsuperscript{1} and Samuel Dorevitch\textsuperscript{1,3}

<table>
<thead>
<tr>
<th></th>
<th>USA</th>
<th>NZ ?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>329,245,000</td>
<td>4,780,000 ?</td>
</tr>
<tr>
<td>Recreation Events</td>
<td>4 billion</td>
<td>58 million ?</td>
</tr>
<tr>
<td>Annual illness</td>
<td>90 million</td>
<td>1.3 million ?</td>
</tr>
<tr>
<td>Costs</td>
<td>US$3 billion</td>
<td>NZ $65 million ?</td>
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</tbody>
</table>
## Notified Diseases in New Zealand (Selected)

<table>
<thead>
<tr>
<th>Disease</th>
<th>2018 Cases</th>
<th>Rate per 100 000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Campylobacteriosis</td>
<td>6,957</td>
<td>142.4</td>
</tr>
<tr>
<td>Cryptosporidiosis</td>
<td>1,611</td>
<td>33</td>
</tr>
<tr>
<td>Giardiasis</td>
<td>1,585</td>
<td>32.4</td>
</tr>
<tr>
<td>Legionellosis</td>
<td>212</td>
<td>4.3</td>
</tr>
<tr>
<td>Leptospirosis</td>
<td>116</td>
<td>2.4</td>
</tr>
<tr>
<td>Listeriosis</td>
<td>30</td>
<td>0.6</td>
</tr>
<tr>
<td>Salmonellosis</td>
<td>1,100</td>
<td>22.5</td>
</tr>
<tr>
<td>Shigellosis</td>
<td>220</td>
<td>4.5</td>
</tr>
<tr>
<td>VTEC/STEC infection</td>
<td>926</td>
<td>19</td>
</tr>
<tr>
<td>Yersiniosis</td>
<td>1,208</td>
<td>24.7</td>
</tr>
</tbody>
</table>

Higher reported recreational water contact: [www.surv.esr.cri.nz](http://www.surv.esr.cri.nz)
Documented waterborne outbreaks in New Zealand, with probable links to drinking water, 2005–2016

<table>
<thead>
<tr>
<th>Year</th>
<th>Incident</th>
<th>Causal agent</th>
<th>Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Confirmed</td>
</tr>
<tr>
<td>2005</td>
<td>Bridge Valley camp</td>
<td>Campylobacter</td>
<td>3</td>
</tr>
<tr>
<td>2005</td>
<td>Hawke’s Bay school camp</td>
<td>Campylobacter</td>
<td>6</td>
</tr>
<tr>
<td>2005</td>
<td>Med student camp, Canterbury</td>
<td>Campylobacter</td>
<td>13</td>
</tr>
<tr>
<td>2005</td>
<td>Otago bowling tournament</td>
<td>Campylobacter</td>
<td>8</td>
</tr>
<tr>
<td>2006</td>
<td>Cardrona Skifield</td>
<td>Norovirus</td>
<td>218</td>
</tr>
<tr>
<td>2006</td>
<td>School camp, Te Kuiti</td>
<td>Campylobacter</td>
<td>2</td>
</tr>
<tr>
<td>2007</td>
<td>School camp, Wellington</td>
<td>Gastro – unknown cause</td>
<td>96</td>
</tr>
<tr>
<td>2007</td>
<td>Northland school</td>
<td>Gastro – viral unknown cause</td>
<td>17</td>
</tr>
<tr>
<td>2008</td>
<td>Springfield</td>
<td>Campylobacter</td>
<td>5</td>
</tr>
<tr>
<td>2008</td>
<td>South Canterbury youth camp</td>
<td>Campylobacter</td>
<td>2</td>
</tr>
<tr>
<td>2010</td>
<td>Golden Bay Holiday Park</td>
<td>Norovirus</td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td>Waiouru Commanders’ Course</td>
<td>Campylobacter</td>
<td>1</td>
</tr>
<tr>
<td>2011</td>
<td>Runanga drinking-water supply</td>
<td>Campylobacter</td>
<td>4</td>
</tr>
<tr>
<td>2012</td>
<td>Darfield drinking-water supply</td>
<td>Campylobacter</td>
<td>29</td>
</tr>
<tr>
<td>2012</td>
<td>Hawke’s Bay camping ground drinking-water</td>
<td>Campylobacter</td>
<td>28</td>
</tr>
<tr>
<td>2012</td>
<td>Cardrona Hotel and water supplies</td>
<td>Norovirus</td>
<td>48</td>
</tr>
<tr>
<td>2013</td>
<td>Nelson Lakes Scout camp</td>
<td>Gastro – unknown cause</td>
<td>13</td>
</tr>
<tr>
<td>2016</td>
<td>Havelock North</td>
<td>Campylobacter</td>
<td>967</td>
</tr>
</tbody>
</table>
Stomach bug lays 110 low in Darfield

CAROLINE KING AND GEORGINA STYLIANOU

Last updated 05:00 25/08/2012

Darfield teen Chloe Walker has had a bucket by her side for a week.
The 13-year-old is among more than 110 people to have been hit with gastroenteritis, a serious stomach illness, in the Darfield area after drinking contaminated water.

Chloe's family were using boiled water after a notice was issued. The warning came after E. coli was found in some parts of the village.

However, on one occasion Chloe "forgot" to use boiled water and brushed her teeth.

The next day, the Darfield High School student had a sore throat.

Then, came the onslaught of vomiting and diarrhoea.

A waterborne outbreak of campylobacteriosis in the South Island of New Zealand due to a failure to implement a multi-barrier approach

Nadja Bartholomew, Cheryl Brunton, Peter Mitchell, Judy Williamson and Brent Gilpin
Darfield 2012 outbreak

23/26 tested same genotype of C. coli

28/26 tested same genotype of C. coli

Water testing

Cases/mm

Campylobacter (cases)  Rainfall (mm)
Darfield Water Supply 2012

3283 population
165mm (6.5 inches) rain in 24 hours
Illness Onset of notified cases in Hawkes Bay

967 notified cases, 235 culture confirmed
5,540 cases in Havelock North

A Chlorination water supply
12 August

Increase cases 7 August
Sources of faecal contamination

https://www.microbe.com/microbial-source-tracking/
Recreational water quality guidelines

• National survey of microbiological water quality 1998-2000
  • 725 samples, 25 sites, 10 microorganisms
• NZ guidelines based on quantitative microbial risk assessment (QMRA) for campylobacteriosis

• *E. coli* concentrations associated with *Campylobacter* infection estimated → numeric limits

<table>
<thead>
<tr>
<th>Percentage Infection</th>
<th>E. coli Concentration (MPN/100 ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;0.1%</td>
<td>&lt;130</td>
</tr>
<tr>
<td>1%</td>
<td>260</td>
</tr>
<tr>
<td>5%</td>
<td>550</td>
</tr>
</tbody>
</table>
Faecal Source Tracking

Molecular markers

Concentrate water samples
100 ml

Extract total DNA

Source specific PCR amplification(s)

Indicative: human, ruminants (pigs, dog, horses, possum), ducks,
1,615 Samples Analysed
Contamination sources identified in water samples

- **Ruminant**: 70% (Strong), 30% (Weaker)
- **Human**: 20% (Strong), 80% (Weaker)
- **Bird**: 50% (Strong), 50% (Weaker)
- **Dog**: 10% (Strong), 90% (Weaker)
- **No Source**: 100% (Strong), 0% (Weaker)
Probability of gastrointestinal illness from ingestion of water containing fresh faecal pollution at densities of and 126 cfu 100 mL$^{-1}$ *E. coli*
WHAT ARE/CAN WE DO TO KEEP OUR WATER SAFE?
Mana Atua – Mana Tangata – Mana Whenua

Te Mana o te Wai
The health of our Wai: The health of our Nation

1. The first is to the water, to protect its health and its mauri.
2. The second is providing for essential human health needs such as drinking water.
3. The third is for other consumption provided that such use does not adversely impact the mauri of freshwater.

NGĀ RITENGA

Te Tiriti o Waitangi te tāhu hi o te Kaupapa o te wai

Te Mana o te wai – Te Mauri o te wai

Te Mana Motuhake o ia wai o ia iwi o ia hapū ki te wai

Te Kaitiakitanga o ngā hapū me nga iwi ki te wai

Te Mana Whakahaere o ngā iwi ki te wai

Incorporated into Policy

OBLIGATION

PRINCIPLES

LEADERSHIP

Mana whakahaere Kaitiakitanga Manaakitanga Governance Stewardship Care, respect

Iwi/Hapū/Māori Landowners/Whānau/Hapori

Crown / Community

Central & local governance
Action for healthy waterways

- Te Mana o te Wai
- New attributes National Policy Statement (NPS)
  - Nutrients, sediments, fish/macroinvertebrates, macrophytes, Oxygen
- No more draining of wetlands, no more piping streams
- Minimum standards wastewater discharges
- All farmers need farm plan by 2025
- No new irrigation or dairy conversions
- Reduce nitrate/nitrogen levels
- 5 m fencing waterways
- Controls intensive winter grazing and feedlots.
- New freshwater QMRA
The Havelock North Water Inquiry

The Havelock North water inquiry panel Dr Karen Poutasi, left, Lyn Stevens QC and Anthony Wilson

https://www.nzherald.co.nz/the-country/news/article.cfm?c_id=16&objectid=11900132
The Havelock North Water Inquiry
Recommendations

• Abolish the Secure Classification System
• Encourage Universal Treatment
• Establish a Drinking Water Regulator
• Amend RMA, Health Act, Accelerate NES Regulations Review
• Establish a Licensing and Qualifications System for Drinking Water Suppliers and Operators
• Review and Strengthen Enforcement of Water safety plans
• Improve the Testing and Laboratories Regime
• Prohibit New Below-ground Bore Heads
Ministry of Health

• Changes to the Drinking Water Standards
  – Requirement for total coliforms in addition to *E. coli*.
  – Removal of presence/absence testing (must be quantitative)
  – Change to chlorine contact times, log credits

• Health Act 31 July 2019
  – Remove requirement to consult 3 years, gazette 2 years
  – Remove all practical steps
  – Water Safety Plans must include timetables
  – Streamline process for appointment of drinking water assessors
  – Raise public health to be equal or greater requirement than affordability
Three Waters Review (DIA)

• Improve the regulation and supply arrangements of drinking water, wastewater and stormwater

• A new regulatory framework for drinking water will include:
  – an extension of the regulatory coverage to all drinking water suppliers, except individual household self-suppliers;
  – a multi-barrier approach to drinking water safety, including mandatory disinfection of water supplies, with exemptions only in appropriate circumstances;
  – stronger obligations on water suppliers and local authorities to manage risks to sources of drinking water;
  – strengthened compliance, monitoring and enforcement of drinking water regulation.

• While regional councils will remain the primary regulators for the environment, there will be stronger central oversight of wastewater and stormwater regulation, including:
  – requirements for wastewater and stormwater operators to report annually on a set of national environmental performance measures;
  – national good practice guidelines for the design and management of wastewater and stormwater networks; and
  – monitoring of emerging contaminants in wastewater and stormwater, and coordinating national responses where necessary.

• New drinking water regulator
OneHealth Opportunities...

• Ongoing Research Need
  – Evidence base for policy and ongoing evaluation of effectiveness
  – Understand sources and transmission pathway of micro-organisms
  – Transition to *E. coli* PLUS

• Document and investigate disease incidence
  – Learn (and relearn) how contamination occurs
  – Raise awareness to ensure importance is recognised

• Recognise and respond to change
Acknowledgements

- New Zealand Ministry of Health, and Ministry for Primary Industries.
- MBIE Strategic Science Investment Fund & Health Research Council of New Zealand
- New Zealand Public Health Unit staff, and clinical laboratories across New Zealand
- ESR Health Intelligence, Epidemiology and Data and Informatics teams: Sarah Jefferies, Shevaun Paine, Jill Sherwood, Andrea McNeill, Yvonne Galloway, Dean Reyneke, Claire Newbern, Tim Wood, Michael Addiddle, Liza Lopez, Charlotte Gilkison, Giles Graham, Pauline Quinn, Andrew Crooke, Dwyllis Maggs, Ben Waite, Mehnaz Adnan, Ian Tompson, Tiffany Walker, Graham Mackereth, Tammy Hambling, Chris Hewison,
- ESR Enteric Reference Laboratory: Jackie Wright, Hugo Stydom, Karen Cullen, Penelope Hancock, David Duncan, Kirti Deo, Angela Brounts,
- Christchurch ESR: Maurice Wilson, Paula Scholes, Beth Robson, Susan Lin, Angela Cornelius, Lucia Rivas, Una Ren, Marilyn Piercy, Chris Nokes, Brent Gilpin
- Sequencing Laboratory and Bioinformatics teams: Joep de Ligt, Una Ren, Hermes Perez, Jing Wang, Yoryea Mantziou, Cat Edwards, Daniel Hudson, Naveena Karki
- Massey University: David Hayman, Nigel French, Ji Zhang, David Wilkinson, Anne Midwinter, Patrick Biggs
- Hawkes Bay DHB: Nicholas Jones, Rachel Eyre and team
- Hawkes Bay Regional Council, Hastings District Council, Tonkin & Taylor
ESR Water & Wastewater Science & Research

Clean, safe water for everyone, everywhere

- Human Health
- Mātauranga Māori
- Contaminants
- Risks
- Solutions

Thankyou
## Outbreaks due to contamination surface water sources

<table>
<thead>
<tr>
<th>Year of Outbreak</th>
<th>Location</th>
<th>Pathogens</th>
<th>Cases Confirmed</th>
<th>Total Cases Estimated</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>North Battleford, SK, Canada</td>
<td><em>Cryptosporidium parvum</em> type 1</td>
<td>375</td>
<td>5,800–7,100</td>
<td>50 hospitalised</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Sewage discharges upstream drinking water intake</td>
</tr>
<tr>
<td>2010</td>
<td>Östersund, Sweden</td>
<td><em>Cryptosporidium</em></td>
<td>&gt;29</td>
<td>27,000</td>
<td>270 hospitalised</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td>Sweden</td>
<td><em>Cryptosporidium hominis</em></td>
<td></td>
<td>18,500</td>
<td></td>
</tr>
<tr>
<td>2002</td>
<td>Spain</td>
<td><em>Shigella sonnei</em></td>
<td>181</td>
<td>756</td>
<td>Heavy rainfall</td>
</tr>
<tr>
<td>2004</td>
<td>Norway</td>
<td><em>Giardia</em></td>
<td>1,300</td>
<td>4,000-6,000</td>
<td>Lake</td>
</tr>
<tr>
<td>2008</td>
<td>Sweden</td>
<td><em>Norovirus</em></td>
<td>33</td>
<td>2,400</td>
<td>Heavy rainfall</td>
</tr>
<tr>
<td>2013</td>
<td>Oregon, USA</td>
<td><em>Cryptosporidium</em></td>
<td>23</td>
<td>2,780</td>
<td>Heavy rainfall</td>
</tr>
</tbody>
</table>

Outbreaks due to contamination ground water sources

<table>
<thead>
<tr>
<th>Year</th>
<th>Location</th>
<th>Pathogens</th>
<th>Cases Confirmed</th>
<th>Total Cases Estimated</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>Walkerton, ON, Canada</td>
<td><em>Escherichia coli</em> O157:H7, <em>Campylobacter</em></td>
<td>163 (E) 105 (C) 12 both</td>
<td>2,300 27 HUS 7 deaths</td>
<td>Cattle manure Rainfall Treatment failure</td>
</tr>
<tr>
<td>2000–01</td>
<td>Asikkala, Finland</td>
<td><em>Campylobacter jejuni</em></td>
<td>71</td>
<td>1,450</td>
<td>Rainfall No treatment</td>
</tr>
<tr>
<td>2002</td>
<td>Transtrand, Sweden</td>
<td>Norovirus</td>
<td>4</td>
<td>~500</td>
<td>Leaking sewer pipe No treatment</td>
</tr>
<tr>
<td>2009</td>
<td>Tune, Denmark</td>
<td><em>Campylobacter jejuni</em></td>
<td>~770</td>
<td></td>
<td>Heavy rainfall</td>
</tr>
<tr>
<td>2010</td>
<td>Koge, Denmark</td>
<td><em>Campylobacter jejuni</em></td>
<td>61</td>
<td>~400</td>
<td>Heavy rainfall</td>
</tr>
</tbody>
</table>

### Outbreaks due to contamination in reticulation

<table>
<thead>
<tr>
<th>Year</th>
<th>Location</th>
<th>Pathogens</th>
<th>Cases Confirmed</th>
<th>Cases Estimated</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>Nokia, Finland</td>
<td><em>Campylobacter</em> spp., <em>Norovirus</em>, <em>Giardia</em>, <em>Salmonella</em> spp., <em>Clostridium difficile</em>, Rotavirus</td>
<td>2 deaths</td>
<td>6,500</td>
<td>cross-connection at sewage treatment plant</td>
</tr>
<tr>
<td>2008</td>
<td>Alamosa, CO, USA</td>
<td><em>Salmonella</em></td>
<td>124</td>
<td>1300</td>
<td>vermin contamination of water storage tank</td>
</tr>
<tr>
<td>2008</td>
<td>Adliswil, Switzerland</td>
<td>pathogens not identified</td>
<td>-</td>
<td>180</td>
<td>cross-connection at sewage treatment plant</td>
</tr>
<tr>
<td>2008</td>
<td>Northampton, England</td>
<td><em>Cryptosporidium cuniculus</em></td>
<td>22</td>
<td>422</td>
<td>Rabbit in backwash tank</td>
</tr>
<tr>
<td>2010</td>
<td>Saratoga Springs, USA</td>
<td><em>Campylobacter</em></td>
<td>17</td>
<td>&gt;333</td>
<td></td>
</tr>
</tbody>
</table>