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

Nadia Bartholomew, Cheryl Brunton, Peter Mitchell, Judy Williamson and Brent Gilpin

ABSTRACT

Outbreaks of waterborne gastroenteritis continue to occur in developed countries. Darfield, a rural town in the South Island of New Zealand experienced an outbreak of campylobacteriosis following a transgression of *Escherichia coli* on 16 August 2012. A descriptive outbreak investigation was performed. As a result, 29 cases had a laboratory-confirmed diagnosis of campylobacteriosis and 138 were identified as probable cases. Heavy rains, contamination of water with animal effluent from nearby paddocks and failures in the treatment of drinking water led to pathogens being distributed through the town's water supply. A multi-barrier approach is advocated to ensure the quality of water and many countries have legislation or programmes to address this. Although legislation for water safety plans based on a multi-barrier approach is in place in New Zealand, at the time of the outbreak it was not a requirement for the Darfield water supply. In addition, despite the awareness of the importance of a multi-barrier approach, competing interests, including those from the agricultural industry and financial restraints on water suppliers, can prevent it from being implemented. Governments need to be more willing to enforce legislation and standards to protect the public from waterborne disease.

Key words | *Campylobacter*, drinking water, gastroenteritis, multi-barrier approach, waterborne

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INTRODUCTION

Outbreaks of waterborne gastroenteritis occur all too frequently in developed countries. Perhaps the most widely known outbreak and one that had implications for water suppliers around the world occurred in Walkerton, Ontario where over 2,000 people became ill and seven people died following contamination of the drinking water supply with *Escherichia coli 0157* (O'Connor 2002). Other large outbreaks have occurred in Milwaukee where 600 people were confirmed with cryptosporidiosis and over 400,000 affected (Mackenzie *et al.* 1994) and France where 206 cases were affected by multiple pathogens (Gallay *et al.* 2006). The largest waterborne outbreak in New Zealand, affecting 218 people, occurred at Cardrona in the South Island in 2006. The causative organism in that outbreak was norovirus. However, between 2007 and 2012 there were 166 waterborne outbreaks in New Zealand reported involving 827 people (The Institute of Environmental Science & Research Ltd 2007–2011). Common contributing factors were an untreated or inadequately treated drinking water supply, source water quality inferior to normal (for example, following heavy rainfall resulting in turbid water and ineffective treatment) and contamination of the water source. In New Zealand the Health (Drinking Water) Amendment Act 2007 requires drinking water standards to be adhered to and water safety plans (WSPs) to be written for suppliers servicing more than 500 people. These

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requirements have been mandatory since July 2013 for suppliers servicing more than 5,000 people, although smaller water suppliers will not be required to comply until at least July 2014. This means some communities remain vulnerable to poor water management strategies and their consequences.

We describe a waterborne outbreak that affected over 130 people which would have been prevented had a multi-barrier approach been taken such as used in WSPs.

Darfield is a rural town in the South Island of New Zealand, with a reticulated water supply that services a population of approximately 3,280. Historically, the town sourced water from the nearby Waimakariri River via three infiltration galleries 7 metres deep and 100 metres from the river. The water was not filtered but was chlorinated. Since November 2011, however, the main source of water has been a deep well with supplementation from the Waimakariri River source. This supply was not chlorinated. On 18 June 2012 there was a pump failure at the deep well and water was subsequently sourced only from the Waimakariri River. The change of water source resulted in reinstatement of chlorination by the supplier. Only one of the three infiltration galleries was in use during this period due to the lower level of turbidity in this infiltration gallery. This fed into a treatment plant consisting of a single chlorinator which sent treated water to a single reservoir. From the reservoir water was pumped to the township. Water samples taken from the reticulation approximately weekly during June, July and the beginning of August found less than one coliform and *E. coli*. However, on 16 August, 89 coliforms and 70 *E. coli* were found on sampling of the reticulated supply. Despite issuing boil water notices and additional manual chlorination of the reservoir, 13 cases of gastroenteritis were notified to the public health unit, Community and Public Health (C&PH), on 22 August and an outbreak investigation was initiated. A community meeting was held on 23 August, during which it became apparent that far more people had been ill than was initially suspected and that sporadic episodes of gastroenteritis had occurred since mid-July. Early laboratory results indicated several cases had campylobacteriosis. The pump was replaced on 22 August and following three days of repeated water testing negative for coliforms and *E. coli*, the boil water notice was lifted on 21 August.

METHODS

Case investigation

A questionnaire was developed that focused on the drinking water supply as the likely source of the outbreak as well as including questions about other risk exposures. Notified cases had questionnaires completed by telephone interviews and others were self-completed following distribution at the public meeting, through the Selwyn District Council offices, the medical centre and a local community website. Questionnaires were checked for quality and completeness of responses and cases were contacted for further information if required, before the questionnaire data were entered into a database.

The case definitions used were as follows.

A person who had been in Darfield between 14 July and 30 August 2012, who was not overseas during the 10 days before the onset of symptoms and for whom there was no medical or other likely explanation for their symptoms and who either had:

(i) diarrhoea and/or abdominal pain with fever – for at least 1 day (probable case of campylobacteriosis);

or

(ii) laboratory-confirmed campylobacteriosis (confirmed case).

Laboratory investigation

Symptomatic cases were requested to provide stool samples for testing. All specimens were tested for *Campylobacter*, *Salmonella*, *Shigella*, *Yersinia* and norovirus and where the stool was fluid *Giardia* and *Cryptosporidium* were also tested for. Children under 6 years were additionally tested for rotavirus, and if stool was blood-stained, for *E. coli 0157*. Stool samples were taken from chicken and sheep in paddocks close to the well on 17 September and tested for the presence of *Campylobacter*. Isolates were analysed by pulsed field gel electrophoresis (PFGE) with *SmaI* and *KpnI* restriction enzymes using the standardized PulseNet protocol (Gilpin *et al*. 2012).

After cases were notified to the C&PH, one-off water samples were taken from a residential water tank on 27 August, and the infiltration gallery in use at the time of the transgression and the Waimakariri River on 10 September.

Environmental investigation

Information was requested from the District Council regarding water supply monitoring, including treatment parameters and water usage and information on rainfall and Waimakariri River flows from the regional council, Environment Canterbury (ECan). A site visit was also conducted to inspect the wells, the chlorinator and the reservoir.

Statistical analyses

A descriptive analysis was performed on the data from the questionnaires using SPSS Statistics (SPSS Inc. 2008). Duration of illness was estimated by duration of the most prolonged symptoms.

RESULTS

Laboratory investigations

Thirty-five cases submitted stool samples of which 29 were positive for *Campylobacter*. Twenty-three samples were positive for *C. coli,* three were also positive for *C. jejuni* and one for *Giardia*. Three cases were positive for *C. jejuni* only, and for three cases no further subtyping was done. All cases of *C. coli* had the genotype Sm0131:Kp0132 (Figure 1). All specimens (where tested) were negative for *Salmonella*, *Shigella*, *Yersinia*, *Rotavirus*, *Norovirus* and *E. coli 0157*.

The water samples taken from the Waimakariri River, the infiltration gallery and residential water tank were all negative for *Campylobacter*. This may have been due to the time period between the transgression and the sampling and the absence of heavy rainfall at the time of sampling. Sixteen sheep stool samples were taken, four of which were positive for *C. jejuni* and one for *C. coli*. The *C. coli* strain (genotype Sm0132:Kp0133) isolated in sheep was very closely related to the strain isolated from human cases (Figure 1).

Analysis of questionnaires

One hundred and nine cases met the definition for probable campylobacteriosis, of whom 94% lived in Darfield. The characteristics of the cases are documented in Table 1 and the ages of cases in Figure 2. Confirmed and probable cases had similar proportions of symptoms, as shown in Table 2.

There was no commonality of risk factors other than all cases having drunk unboiled water from the local water supply. The local bakery was the most frequented food premise with 35% of cases consuming its products. The most common sites for recreational water contact were public swimming pools, with 17% of cases visiting these. Thirty-five per cent of cases had contact with children in nappies. Animal contact was common: 84% had contact with a household pet, 24% with a farm animal and 5% with another animal.

Environmental investigation

Infiltration gallery 3 (the only one in use at the time of the transgression) was situated in a small recession in an unsecure privately owned paddock approximately 100 metres from the Waimakariri River and 12 metres below a cliff bounded by predominantly agricultural land. The well head was not fenced off and farm animals had grazed in the paddock although it was not known how recently. At the time of the transgression the chlorine cylinder was empty and the 'empty' alarm mechanism had been disconnected. The freely available chlorine (FAC) analyser and the turbidity analyser had also not been calibrated, making readings unreliable.

Between 30 July and 16 August heavy rains (164 mm) had fallen in the area. Although the river levels had risen only modestly, recorded turbidity levels in the water supply had doubled by the 15 August.

DISCUSSION

Figure 4 shows the relationship between rainfall, recorded chlorination and turbidity, and campylobacteriosis incidence. While no direct microbiological link was demonstrated between the cases and the local water supply, the combination of several potential causative factors strongly suggests the water supply was the likely source of the outbreak. Heavy rainfall and increased turbidity preceded the transgression. In the absence of significant filtration and without any effective disinfection by

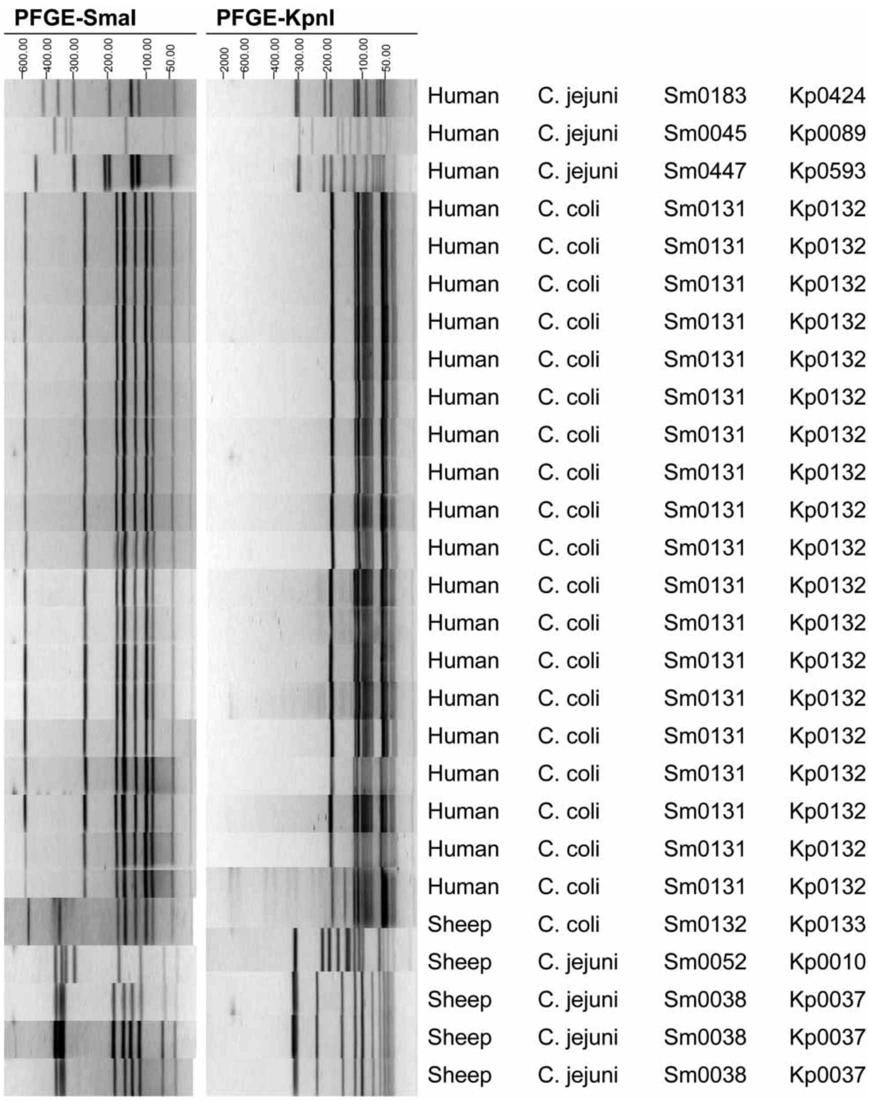

Figure 1 | *SmaI* and *KpnI* pulsed field gel electrophoresis patterns of isolates from human cases and sheep stool samples.

chlorination pathogenic organisms would have been able to enter and survive in the drinking water supply. In addition, the only common risk exposure among cases was having drunk unboiled water from the local water supply.

Although *E. coli* and coliforms were found on microbial sampling of the supply on 16 August, it is likely, given the incubation time for campylobacteriosis, that the major contamination event probably occurred around 13–14 August. Figures 3 and 4 show that some cases developed symptoms as early as 14 July. This suggests that a low level of intermittent contamination was occurring for at least a month prior to the transgression on 16 August, which is consistent with the time frame when the Waimakariri River became the sole source of drinking water for Darfield.

One hundred and thirty-eight confirmed or probable *Campylobacter* cases were identified in this outbreak, representing approximately 4% of the Darfield population. A number of other cases of gastroenteritis were also identified that did not meet the case definition but given the estimate that there are 222 cases not notified for every notified case of acute gastrointestinal illness (Lake *et al.* 2000) it is likely that a much greater number of residents were affected. In this outbreak only one case was hospitalized and no fatalities occurred. Confirmed and probable cases had similar

Table 1 | Characteristics of cases

	Confirmed campylobacteriosis	Probable campylobacteriosis
No.	29	109
Age range (mean)	1 y–89 y (35.4 y)	11 m–83 y (29 y)
Male:Female ratio	1:1.4	1.1:1
Average duration of illness	6.24 days	4.94 days
No. with diarrhoea	29	105
No. with abdominal pain and fever	21	48
No. hospitalized	1	0
Per cent who drank unboiled Darfield water	100%	100%
Onset:		
14 July–14 August	3	9
15–25 August	26	100

types and durations of symptoms, apart from fever, as shown in Table 2. Since the difference in the incidence of fever between the confirmed and probable cases was across the age groups (apart from the 15–24 year olds), having a fever may have precipitated cases to seek medical attention (72% of confirmed cases compared with 45% of probable cases) and subsequently be tested because of perceived severity. Thus a testing bias may be an explanation for the difference in the incidence of fever between the confirmed and probable cases. The similarity in symptoms otherwise and the high percentage of faecal samples positive for *Campylobacter* (83%) indicates that the case definition was appropriate and that *Campylobacter* was the causative organism of this outbreak. The proportion of confirmed cases to probable cases was lowest in the 5–14 year age group possibly because 80% did not seek medical advice for their illness.

Heavy rainfall has been implicated in many waterborne outbreaks including Walkerton (Auld *et al.* 2010). Curreiro *et al.* (2001) found a significant association between extreme rainfall and waterborne outbreaks in the United States. In New Zealand, elevated *Campylobacter* levels in water sources have occurred following rainfall events (Nokes & Kikkert 2007). It is thought that heavy rainfall may lead to changes in the direction of flow of water through channels that would not normally occur, allowing organisms to enter the water supply (Hunter 2003). In addition, the increase in turbidity resulting from rainfall can also stress water systems with inadequate water treatment. Drinking water supply managers therefore need to take these situations into consideration. Auld *et al.* (2010) have suggested that supplies should be monitored more frequently when there is potential for weather events to cause contamination, particularly where surface water is used.

The mechanism for contamination of the water supply in this case was considered to have been either runoff of animal effluent from paddocks flowing into the Waimakariri River and from there into the infiltration gallery, or effluent that may have contaminated the gallery directly by seepage through the ground which was composed of alluvial gravels (Tonkin and Taylor Environmental Engineering Consultants 2010). Microorganisms have been shown to travel easily through this type of substrate (Sinton *et al.* 2005). In either case, multiple failures in the treatment of the water led to pathogens being distributed through the town's water

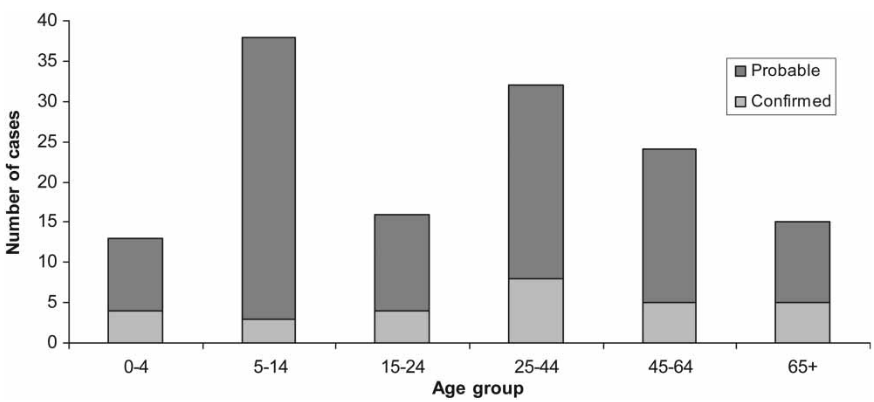

Figure 2 | Age of cases in the Darfield outbreak.

Table 2 | Symptoms by case definition

	Diarrhoea	Vomiting	Abdominal pain	Fever
Confirmed cases (29)	29	8	29	21
	100%	28%	100%	72%
Probable cases (109)	105	28	103	49
	96%	26%	94%	45%

supply. These included a failure to manage turbidity rendering any available chlorine ineffective for disinfection, an eventual lack of chlorination and an absence of filtration processes to prevent protozoal contamination. It was fortunate in this incident that only one case of giardiasis was identified, indicating a low level of contamination. If contamination levels had been higher, a larger number of giardiasis cases could have been expected.

Diffuse microbial pollution from agricultural use can come from runoff, livestock accessing unfenced streams and cattle crossing rivers (Ministry of Health 2005). Surface water sources are known to be frequently contaminated with pathogens. The New Zealand freshwater microbiology research programme (McBride *et al.* 2002) found pathogenic viruses and *Campylobacter* at least once in each of 25 river sites monitored over 15 months.

Lack of source water protection has repeatedly led to waterborne outbreaks occurring elsewhere. Examples include Walkerton, where farms were thought to be the source of *E. coli 0157* contamination (O'Connor 2002), Orangeville, where it was thought that surface drainage from farms led to *Campylobacter* being distributed in the water supply (Millson *et al.* 1991) infecting over 200 people and Penticton, where 3,000 people were infected with giardiasis due to the water source being frequented by domestic animals and *Giardia*-infected beavers (Moorehead *et al.* 1990). It is not surprising, therefore, that the Darfield water supply most probably became contaminated with *Campylobacter*, given the well was below paddocks grazed by sheep, drew river water into which pasture runoff flowed, and was situated in a paddock that at some time had been grazed by sheep.

The major causative organism, *C. coli* has been isolated from cattle, sheep, pigs, birds and surface water and, occasionally, humans in New Zealand (Gilpin *et al.* 2012). The consequences of this outbreak could have been far more serious had the outbreak been due to *E. coli 0157*, which in Canterbury particularly affects children in rural areas. *E. coli 0157* has also caused several large waterborne outbreaks in other countries (Swerdlow *et al.* 1992; Bopp *et al.* 2003; Auld *et al.* 2010).

A multi-barrier approach to safe drinking water has repeatedly been emphasized as important in addressing source water protection, treatment plant processes and prevention of contamination in the supply reticulation. The protection of source water, especially in terms of agricultural pollution can be a challenge, primarily due to its diffuse nature and being subject to natural variability. In New Zealand the National Environmental Standards (NES) for Sources of Human Drinking Water and the Resource Management Act 1991 address source water protection. The NES require councils to consider the effects

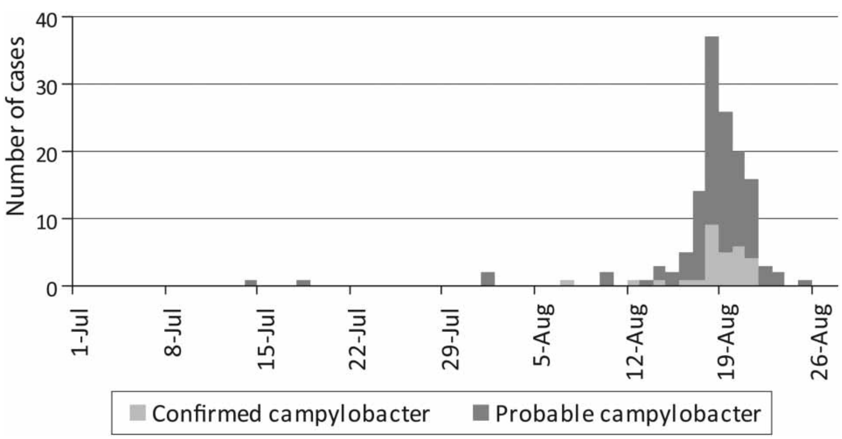

Figure 3 | Onset dates of probable and confirmed campylobacteriosis cases.

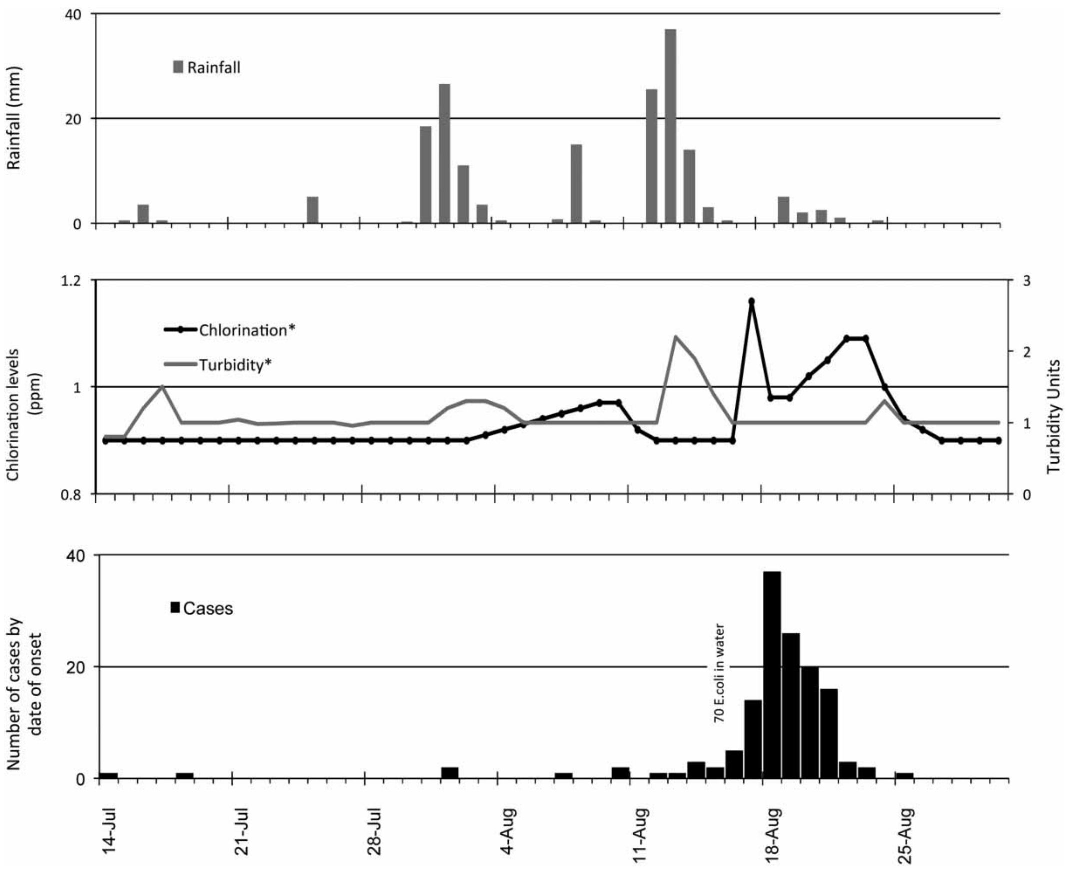

Figure 4 | Summary chart of cases and environmental factors associated with the Darfield outbreak July–August 2012. *The turbidity analyser and freely available chlorine (FAC) analyser were not calibrated making these readings unreliable. The peak in chlorine levels on 16 August was due to the manual chlorination that occurred following positive *E. coli* samples in the reticulated water supply.

of granting water and discharge permits and permitting activities, on drinking water sources (Ministry for the Environment 2009). Although these standards may prevent new resource consents having adverse effects being granted, there is no requirement for activities granted consent prior to the introduction of the standards to comply with them.

Many countries require source water assessments or source water protection to be addressed (European Commission 2000; United States Environmental Protection Agency 2012). However, competing interests from agricultural industry can influence the extent to which these plans are successful (European Environmental Bureau 2012). Livestock has played an important role in New Zealand's economy for many years but with a large increase in dairy cattle, especially in the South Island in the last 20 years (Centre for Public Health Research 2013), there has been tension between source water protection and economic interests. This could have long-term implications on drinking water quality and therefore the potential for health effects.

Most countries have adopted standards for drinking water. In the USA the Safe Drinking Water Act ensures the quality of water by setting requirements for the testing of drinking water as well as setting national standards, while at the same time considering the available technology and costs (United States Environmental Protection Agency 2004). The European Drinking Water Directive also sets similar standards for its member countries and requires them to report against these (European Commission 1998). In New Zealand, the Health (Drinking Water) Amendment Act 2007 addresses treatment plant processes and monitoring through the Drinking Water Standards (Ministry of Health 2008). The drinking water standards specify the levels of monitoring required and the operational management for the protection from protozoa for each category of drinking water supplier.

In the Darfield incident, neither the monitoring of the drinking water supply nor the lack of protection from contamination by protozoa was compliant with the drinking water standards. Chlorination does not prevent protozoal contamination and therefore the town's population was vulnerable to *Giardia* and *Cryptosporidium*. Had the local council put in place filtration processes for the removal of protozoa, this would also have resulted in a reduction in turbidity, enabling any chlorine present to be more effective.

Compliance with the drinking water standards was deferred by the New Zealand government for 3 years for each category of drinking water supplier. For the Selwyn District Council this means that the drinking water standards do not come into force until 2014 for Darfield, as the drinking water supplies between 501 and 5,000 people. Therefore, at the time of the outbreak they were not required to be compliant with the drinking water standards or to have a WSP. A WSP formally identifies possible causes of contamination and measures to mitigate these risks. Under the Health (Drinking Water) Amendment Act 2007 a drinking water supplier must take all 'practicable' steps to comply with the drinking water standards. What the term 'practicable' steps actually means in terms of preventable measures drinking water suppliers can take is open to debate, especially in regards to affordability. Currently, a water supply is deemed to be taking all 'practicable' steps if they have an approved WSP implemented. However, if a WSP states that the supplier cannot afford to comply with the drinking water standards should the WSP be approved? Potentially, the result could be that there are no repercussions for drinking water suppliers who fail to meet the compliance criteria in the drinking water standards leaving the public vulnerable to such incidents as occurred in Darfield.

Despite all drinking water suppliers having to comply with legislation by 1 July 2016, approximately 14% of New Zealanders are supplied with drinking water from unprotected source water and 22% of the population's drinking water supplies are not compliant overall with the drinking water standards (Ministry of Health 2012). More worryingly, 73% of the population's drinking water supplies do not have WSPs in place. In the European Union, 15 member states were not compliant with the monitoring of their drinking water between 2005 and 2007. The European Commission identified that better national enforcement was required to improve the monitoring of drinking water (Hulsmann 2011). In the United States, in 2011, over 9.5 million people were exposed to violations of the total coliform rule, i.e., inadequate monitoring of total coliforms and greater than 5% of samples containing coliforms (United States Environmental Protection Agency 2013a, b). The presence of legislation alone does not appear to be sufficient to ensure that drinking water is safe as compliance is still inadequate.

CONCLUSION

A multi-barrier approach to drinking water supplies is advocated to ensure that if one protective mechanism is removed others are in place to ensure a safe supply. Failure of a single-barrier approach was highlighted in this incident as the only intended barrier was chlorination. Even if operational, chlorination alone was never going to be adequate. Illness in the population served by the supply was a real possibility if ever the effectiveness of chlorination was compromised by an increase in turbidity, let alone when there was an absence of chlorination associated with microbiological contamination. Competing interests, such as from the agricultural industry and financial constraints on drinking water suppliers may prevent multi-barrier approaches from being put in place. Governments need to be willing to enforce legislation and the standards that are currently in place if the public are to be protected from waterborne disease.

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