

Chapter 1: Introduction

Contents

1.1	Introduction	3
1.1.1	Purpose of the guidelines	3
1.1.2	Background	4
1.1.3	Waterborne diseases in New Zealand	5
1.1.4	The cost of providing potable drinking-water	13
1.1.5	The benefits of potable drinking-water supplies	14
1.2	Ministry of Health public health protection strategy for drinking-water 1993–1995	18
1.2.1	Strategy development	18
1.2.2	Outline of the strategy	19
1.2.3	Planned milestones	19
1.2.4	Desired outcomes	20
1.2.5	Promotion of awareness of public health issues related to drinking-water	20
1.2.6	Outputs achieved by 1995	20
1.3	Strategy development 1995–2000	21
1.3.1	Consultation	21
1.3.2	Inclusion of protozoa in the DWSNZ	22
1.3.3	Human resource development	22
1.3.4	DWSNZ 2000	22
1.4	Strategy development 2000–2005	23
1.4.1	Consultation	23
1.4.2	Water safety plans	23
1.4.3	Legislative development	24
1.4.4	Development of the DWSNZ 2005	25
1.4.5	Development of the drinking-water assistance programme	27
1.5	Operational development of the drinking-water management programme 2005–2009	28
1.5.1	The Drinking-water Assistance Programme, DWAP	28
1.5.2	Legislation: The Health (Drinking Water) Amendment Act 2007 (Part 2a of the Health Act 1956 – the Act)	29
1.5.3	The 2008 revision of DWSNZ 2005	30

1.5.4	Tankered drinking-water supplies	30
1.5.5	Development of specifications for Rural Agricultural Drinking-water Supplies (RADWS)	31
1.5.6	Point-of-use and point-of-entry drinking-water treatment appliances standards	31
1.6	Tools for promoting potable drinking-water supplies	32
1.6.1	Introduction	32
1.6.2	Four tools used by the World Health Organization	33
1.6.3	The six guiding principles of drinking-water safety	33
1.6.4	Drinking-water Standards for New Zealand	35
1.6.5	Guidelines for Drinking-water Quality Management in New Zealand	39
1.6.6	Water safety plans	39
1.6.7	Public health grading of drinking-water supplies	41
1.6.8	Drinking-water assessment	41
1.6.9	Monitoring	41
1.6.10	Surveillance	42
1.6.11	Identifying priority 2 and priority 3 determinands	42
1.6.12	Register of Community Drinking-water Supplies and Suppliers in New Zealand	43
1.6.13	Annual Review of Drinking-water Quality in New Zealand	44
1.6.14	Register of recognised laboratories	44
1.6.15	Records	45
1.7	Other drinking-water requirements	46
1.7.1	Drinking-water quality at airports	46
1.7.2	Drinking-water quality in shipping	47
1.8	Emergency supplies and emergencies	48
Appendix 1: Statistical issues that relate to the Drinking-water Standards of New Zealand		49
A1	Compliance rules for percentile standards	50
A2	Handling non-detects	56
References		58

List of tables

Table 1.1:	Numbers and rates of notifiable diseases with waterborne transmission potential, 2004–2013	9
Table 1.2:	Number of outbreaks and associated cases recorded for enteric disease and waterborne enteric disease, 2004–2013	10
Table 1.3:	Documented waterborne outbreaks in New Zealand, with probable links to drinking water, 2005–2016	11
Table 1.4:	Economic benefits arising from water and sanitation improvements	15
Table 1.5:	Examples of priority allocation in the DWSNZ	43
Table A1.1:	Numbers of samples and allowable transgressions needed to keep maximum risks below 5 percent when assessing compliance with a 95th percentile standard	51
Table A1.2:	Allowable exceedances (for 95 percent confidence that the MAV is exceeded for no more than 5 percent of the time)	55

List of figures

Figure 1.1:	Epidemic versus endemic/sporadic disease	12
Figure A1:	Bayesian confidence of compliance curves for a 95th percentile standard, using Jeffreys' uninformative	52
Figure A2:	Fitting a lognormal distribution to >L data (where L = 5), and extrapolating back to obtain values of <L data	57

1.1 Introduction

1.1.1 Purpose of the guidelines

A wide range of gastrointestinal diseases can be caused by ingestion of food or drink that is contaminated by pathogenic micro-organisms or by toxic chemicals. Control of these is an important feature of public health. This is done by regulating food safety, administered by the Ministry of Primary Industries and regulating safety of community drinking-water supplies, administered by the Ministry of Health.

The purpose of these *Guidelines for Drinking-water Quality Management for New Zealand* is to provide information on the tools used by the Ministry of Health to promote the provision, by suppliers, of drinking-water that is safe to drink. The development of these tools commenced in 1993. This introduction to the *Guidelines* puts the Ministry's tools in their historical context.

1.1.2 Background

In 1992 the public health oversight of drinking-water quality management in New Zealand was in disarray after five years of central and local government restructuring and retrenchment. The (then) Department of Health was receiving little information about the quality of public drinking-water supplies (Taylor 1993a). However, an independent survey (Ogilvie 1989) had shown that at least 45 to 50 percent of water suppliers did not monitor their chlorine dosage satisfactorily, 28 percent never tested the bacteriological quality of water after it entered the distribution system, and another 30 percent tested only four times per year. Thus, for most of the year, the microbiological quality of the water was unknown. In 1991 bacterial quality was reported for just 462 of the water supplies in New Zealand. As the drinking-water management tools came into operation the number of known supplies increased until, as at April 2015, 1,470 community water supplies were listed on the Register of Drinking-water Suppliers for New Zealand.

After the Department of Health was restructured into the Ministry of Health in 1993, an initial appraisal of the public health safety management of the drinking-water industry was carried out (Taylor 1993a, 1993b). The opportunity was taken to review and restructure the process of public health management of drinking-water. There were also a number of major governance and structural issues surrounding the management of the water resources and the water industry that might have benefited from review, but responsibility for these lay outside the health portfolio. Therefore the Ministry of Health concentrated on the public health infrastructure, although it has contributed where possible to various governance and structural reviews on related topics carried out by other agencies.

It soon became evident that there were a large number of small supplies about which little or nothing was known, even though the larger municipal supplies were generally well-managed and safe, there were some whose standards were not as good as could be desired.

The Ministry of Health is responsible for the regulation of public health under the Health Act 1956 and subsequent amendments. This includes overview of drinking-water supplies to ensure that the water from these supplies can be drunk without causing illness. A potable drinking-water supply is a fundamental pre-requisite of public health.

In 1993 the World Health Organization (WHO) published the second edition of its *Guidelines for Drinking-water Quality* which updated the information on drinking-water quality requirements from the first (1983) edition. The Ministry of Health used the information in the WHO Guidelines, and the knowledge of deficiencies in the public health management of drinking-water that it had gained from its own review in New Zealand, to publish revised *Drinking-water Standards for New Zealand* in 1995 and to develop a strategic plan and tools to improve the public health safety of New Zealand drinking-water. The standards were further updated in 2000, 2005, and again in 2008.

The *Drinking-water Standards for New Zealand 2000* updated the analytical methods for drinking-water quality and made some minor changes to improve the interpretation and robustness.

Additional new material was included in the *Drinking-water Standards for New Zealand 2005* (DWSNZ) to accommodate the advances that had occurred in the previous five years. This included protocols for the use of ultraviolet light disinfection to inactivate bacteria and protozoa, radically restructuring sections relating to protozoal compliance, and sections on cyanotoxins, small supplies, and tankered drinking-water. New information from the WHO *Guidelines for Drinking-water Quality* (3rd edition, 2004) was included.

The current Standards are *Drinking-water Standards for New Zealand 2005* (revised 2008). They have two main components:

- public health standards for drinking-water quality which list the maximum concentrations of chemical, radiological and microbiological contaminants that can be present in drinking-water without presenting a public health risk
- compliance criteria for community water supplies which specify the sampling frequencies and testing procedures needed to demonstrate with 95 percent confidence that the water complies with the DWSNZ for at least 95 percent of the time, and provide for lesser confidence levels for smaller supplies.

Though the DWSNZ provide performance criteria for drinking-water quality management they do not specify how the quality of water supplies should be managed. That is discussed in this publication, the *Guidelines for Drinking-water Quality Management in New Zealand*, which forms the companion volume to the DWSNZ.

The water properties addressed in the DWSNZ relate to health significance, not to aesthetic qualities. The *Guidelines for Drinking-water Quality Management in New Zealand* (the Guidelines) explain the principles underlying the DWSNZ, how the Maximum Acceptable Values (MAVs) for determinands in drinking-water were derived, and the part that aesthetic quality plays in producing a potable, wholesome and acceptable community drinking-water. The Ministry's drinking-water quality management tools and the scope of the Guidelines are discussed in more detail in section 1.3.

1.1.3 Waterborne diseases in New Zealand

Untreated or inadequately treated drinking-water contaminated with pathogens presents a significant risk to human health. In New Zealand, the overall burden of endemic drinking-waterborne gastrointestinal disease has been estimated at 18,000 to 34,000 cases per year (Ball 2007). Attributing the cause of illness can be complicated by the lack of data collected at the time.

Following recent outbreaks in Canada (eg, Walkerton), Schuster et al (2005) analysed 288 outbreaks in Canada between 1974 and 2001. They found 99 outbreaks (34 percent) occurred in areas served by public supplies, 138 (48 percent) in semi-public supplies (private supplies but providing drinking-water to the public), and 51 (18 percent) in private supplies. The causative organisms, in descending frequency of occurrence, were: *Giardia*, *Campylobacter*, *Cryptosporidium*, Norwalk-type viruses, *Salmonella*, and hepatitis A virus.

In New Zealand, giardiasis, campylobacteriosis, cryptosporidiosis, salmonellosis and as well as acute gastroenteritis in general, are commonly reported enteric diseases with waterborne transmission potential. Norovirus (reported under acute gastroenteritis) also commonly causes waterborne illness, however, it is not notifiable unless the cases are related to an outbreak. Table 1.1 shows the numbers and rates of notifiable diseases with waterborne transmission potential for the period 2004–2013.

Over the last 10 years, approximately 3 to 10% of enteric disease outbreaks in New Zealand recorded a mode of transmission as waterborne. Table 1.2 shows the number of outbreaks and associated cases recorded for enteric diseases and waterborne enteric diseases for the period 2004–2013.

The numbers and rates of potentially waterborne illness notified and reported in Tables 1.1 and 1.2 are known to underestimate the actual burden of illness in the community because not all people who become ill are accounted for in the notifiable disease statistics. Reasons for this include:

- some people are infected but asymptomatic
- some people that are ill do not visit a doctor
- a doctor may fail to report a suspected case
- a doctor may not request faecal specimens
- some people may not submit the requested faecal specimens
- many other potentially waterborne illnesses are not notifiable (eg, norovirus cases – unless outbreak related, or sporadic gastroenteritis cases).

A New Zealand study estimated that out of every 222 community cases of acute gastroenteritis illness only one case is reported to the notification system, Lake et al 2009; Wheeler et al 1999 suggest that only a minority of cases get reported in England.

The term 'waterborne potential' is used here for any illness that could potentially be transmitted by water. This does not mean that an illness was actually transmitted by water. A large number of gastrointestinal infections are associated with other transmission routes (eg, foodborne, person-to person or environmental transmission, eg, Reilly et al 2004). The proportion attributable to each transmission route varies by disease. Finally, only a proportion of those that are linked to waterborne transmission will be directly associated with drinking-water. Other possible waterborne transmission routes include contact with recreational water. But this is not cause for complacency for at least four reasons.

First, the majority of the disease burden occurs in sporadic or endemic cases, not in detected outbreaks¹ (Figure 1.1 demonstrates the distinction between these terms). Therefore, given the publicity that outbreaks attract, the sporadic disease prevalence may be underestimated. To elaborate, some illnesses may often occur in outbreaks (eg, cryptosporidiosis) and so can receive a lot of publicity (eg, Baker et al 1998 and associated news items). Indeed there is a whole book devoted to analysis of outbreaks attributed to poor drinking-water supplies (Hrudey and Hrudey 2004),² including a New Zealand water supply example. However, other illnesses, such as campylobacteriosis, are usually less associated with outbreaks (although these can happen, particularly when water treatment systems are not operated well).³ Health scientists are now in broad agreement that outbreaks form only a minor part of the total drinking-water related illness burden. For example, Dr Jamie Bartram of WHO, in introducing a section on *Investigation of Sporadic Waterborne Disease* in an authoritative text on drinking-water and disease (Hunter et al 2003), states that “a large proportion, and probably the vast majority, of waterborne disease burden arises outside of detected outbreaks. This statement contrasts with the view, predominant until only a few years ago and still periodically heard, that the failure to detect outbreaks of waterborne disease illustrates that this route of disease transmission is largely conquered in industrialised countries” (Bartram 2003).

Second, to identify the endemic and sporadic cases, special epidemiological investigations must be conducted to see if those cases are associated with drinking-water. Because of the cost of resources required to carry out such a study such work is usually not done. When such studies are performed, an association with the degree of drinking-water treatment is often identified. This has been found both overseas (Payment 2003, Hunter et al 2003) and in New Zealand. The New Zealand studies include giardiasis in a city in which two water supplies drawn from the same source received different levels of treatment (Dunedin, Fraser and Cooke 1991); campylobacteriosis in a number of rural water supplies (Eberhardt-Phillips et al 1997), and a Hawkes Bay college; cryptosporidiosis in many communities (Duncanson et al 2000); and microbial and chemical contamination of roof-collected rainwater supplies in Auckland, and associated illnesses (Simmons et al 2001).

¹ For reporting purposes the outbreak case definition is “two or more cases linked to a common source” (ESR 2002 Disease Outbreak Manual p2 (download www.surv.esr.cri.nz)). The sensitivity of surveillance for diseases will often be less, particularly for common enteric diseases where only a small proportion of those infected will advise health officials thereby reducing the chances of identifying a common source.

² Outbreaks of cryptosporidiosis in Milwaukee (USA) and pathogenic *E. coli* in Walkerton (Canada) are the most recent serious examples, where numbers of people died and others gained life-long health impairment (usually renal failure).

³ New Zealand examples include: Queenstown (Thorstensen 1985), Canterbury (Briesman 1987, Stehr-Green et al 1991), Hawkes Bay (McElnay and Inkson 2002). The 1984 Queenstown outbreak affected an estimated 3,500 people, and at least one person affected has since required continual kidney dialysis.

Third, there is a substantial level of faecal contamination of New Zealand freshwaters, including *Campylobacter*, enteroviruses and adenoviruses, even at recreational and water supply abstraction sites (McBride et al 2002). Human and livestock wastes may contain large numbers of pathogens that can present a major threat to public health if released into the environment and result in substantial health costs. Numerous waterborne outbreaks of infectious enteric diseases worldwide have been associated with discharge of effluents and agricultural runoff resulting in human exposure to faecal-contaminated water. Luckily, in general, the larger New Zealand drinking-water supplies are well-managed and generally well-sourced. This has minimised the potential disease level that could have been expected from the level of microbiological contamination of some of the source waters. Cysts and oocysts of protozoan parasites such as *Giardia* and *Cryptosporidium* are frequently found in environmental waters especially in areas of intensive livestock farming (Ionas et al 1999). In the UK, significant costs ranging from £15 to 30 million per annum have been estimated (Pretty et al 2000) to result from the agricultural contamination of drinking-water with zoonoses (diseases transmitted from animals to humans) such as *Cryptosporidium*.

Finally, despite careful and extensive examination of New Zealand drinking waters failing to find any trace of *Campylobacter* in well-treated and disinfected drinking-water supplies, it is present in almost all riverine source water.⁴

In his evidence to the Havelock North inquiry, Dr S Hrudehy (2017) stated:

In closing, the common theme across all of the international outbreak evidence is one of complacency. Our affluent societies have known for many decades how to prevent outbreaks yet we continue to allow them to happen by failing to do what we know needs to be done. In this sense, an analogy may be drawn with recurring outbreaks of communicable diseases like measles and mumps that occur because of a failure to maintain adequate immunization. These circumstances reveal the inevitable tension between individual rights and societal benefit. In the case of drinking water, individual biases about water disinfection and treatment should not be allowed to endanger innocent consumers, especially when such biases are based on urban myths and are not founded on authentic public health evidence.

⁴ A preliminary study occasionally found small concentrations of *Campylobacter* in finished well-treated New Zealand water supplies (Savill et al 2001), but a subsequent full-scale study, using altered laboratory procedures, has failed to repeat that finding (Nokes et al 2004).

Table 1.1: Numbers and rates of notifiable diseases with waterborne transmission potential, 2004–2013

Notifiable disease	2004		2005		2006		2007		2008		2009		2010		2011		2012		2013	
	Cases	Rate ¹	Cases	Rate ¹	Cases	Rate ¹	Cases	Rate ¹	Cases	Rate ¹	Cases	Rate ¹	Cases	Rate ¹	Cases	Rate ¹	Cases	Rate ¹	Cases	Rate ¹
Campylobacteriosis	12,215	298.8	13,836	334.7	15,873	379.3	12,778	302.2	6,694	156.8	7,177	166.3	7,346	168.2	6,686	151.8	7,016	158.3	6,837	152.9
Cryptosporidiosis	611	14.9	888	21.5	737	17.6	924	21.9	764	17.9	854	19.8	954	21.8	610	13.8	877	19.8	1,348	30.1
Gastroenteritis (acute)	1,363	33.3	557	13.5	937	22.4	622	14.7	686	16.1	712	16.5	493	11.3	567	12.9	735	16.6	558	12.5
Giardiasis	1,514	37.0	1,231	29.8	1,214	29.0	1402	33.2	1,660	38.9	1,639	38.0	1,985	45.4	1,934	43.9	1,714	38.7	1,729	38.7
Hepatitis A	49	1.2	51	1.2	123	2.9	42	1	89	2.1	44	1.0	46	1.1	26	0.6	82	1.8	91	2.0
Legionellosis	62	1.5	85	2.1	52	1.2	64	1.5	73	1.7	74	1.7	173	4.0	158	3.6	150	3.4	151	3.4
Leptospirosis	102	2.5	85	2.1	87	2.1	66	1.6	118	2.8	69	1.6	81	1.9	68	1.5	108	2.4	59	1.3
Paratyphoid fever	28	0.7	25	0.6	23	0.5	23	0.5	25	0.6	25	0.6	19	0.4	13	0.3	22	0.5	25	0.6
Salmonellosis	1,081	26.4	1,382	33.4	1,335	31.9	1275	30.2	1,339	31.4	1,128	26.1	1,146	26.2	1,055	23.9	1,081	24.4	1,143	25.6
Shigellosis	140	3.4	183	4.4	102	2.4	129	3.1	113	2.6	119	2.8	104	2.4	101	2.3	132	3.0	137	3.1
Typhoid fever	31	0.8	30	0.7	42	1.0	48	1.1	29	0.7	34	0.8	31	0.7	45	1.0	44	1.0	50	1.1
VTEC/STEC infection	89	2.2	92	2.2	87	2.1	100	2.4	124	2.9	143	3.3	138	3.2	153	3.5	147	3.3	205	4.6
Yersiniosis	407	10.0	383	9.3	453	10.8	502	11.9	508	11.9	430	10.0	406	9.3	513	11.6	514	11.6	485	10.8
Total	17,694	432.9	18,831	455.5	21,066	503.4	17,979	425.2	12,223	286.3	12,449	288.5	12,933	296.1	11,932	270.9	12,652	285.4	12,819	286.7

Data extracted from EpiSurv on 20 June 2014. Rates for cholera and toxic shellfish poisoning are <0.5 per 100,000 population so not included.

¹ Cases per 100,000 population calculated using mid-year population estimates.

Notes:

- All of the diseases included in the table have multiple possible transmission routes but have the potential to be transmitted via water. It is not possible here to attribute a specific number of cases associated with any specific transmission route. Multiple transmission routes are also possible. The number of cases attributable to a specific transmission route will vary by disease.
- The number of cases includes imported cases. The proportion of imported cases varies by disease.

Table 1.2 shows the number of outbreaks and associated cases recorded for enteric diseases and waterborne enteric diseases in New Zealand for the period 2004–2013.

Table 1.2: Number of outbreaks and associated cases recorded for enteric disease and waterborne enteric disease, 2004–2013

Year	Waterborne enteric outbreaks ¹		All enteric outbreaks	
	Outbreaks	Cases	Outbreaks	Cases
2004	24	118	363	4,623
2005	27	184	342	2,365
2006	18	284	483	6,171
2007	15	205	479	7,866
2008	26	159	429	6,311
2009	24	87	587	10,217
2010	56	235	571	6,153
2011	45	141	545	6,715
2012	51	379	659	9,489
2013	62	227	616	6,950

Data extracted from EpiSurv on 20 June 2014.

¹ Includes outbreaks where waterborne transmission was either the primary or secondary mode of transmission reported.

Table 1.3 lists documented outbreaks in New Zealand where waterborne transmission has been implicated as a possible source of infection, from 2005 to 2013. This is an updated version of Table 1 from Ball (2007).

Note that Table 1.3 does not include all waterborne outbreaks that have occurred in New Zealand.

Apart from the Havelock North Inquiry Report, the following search methods were used:

- 1 Literature search using search terms “New Zealand” AND outbreak* AND water* In: Index New Zealand (INNz), Proquest Public Health, PubMed, ScienceDirect, Scopus, Web of Science from 2006–2014
- 2 Search of New Zealand Public Health Surveillance Reports from 2004–June 2014.

Search of EpiSurv from 2005–2014 for outbreaks that reported 10 or more cases and were not household/family related.

Table 1.3: Documented waterborne outbreaks in New Zealand, with probable links to drinking water, 2005–2016

Year	Incident	Causal agent	Cases		Source	Reference
			Confirmed	Probable		
2005	Bridge Valley camp	<i>Campylobacter</i>	3	10	EpiSurv	
2005	Hawke's Bay school camp	<i>Campylobacter</i>	6	34	NZPHSR	https://surv.esr.cri.nz/PDF_surveillance/NZPHSR/2006/NZPHSR2006March.pdf
2005	Med student camp, Canterbury	<i>Campylobacter</i>	13	21	EpiSurv	
2005	Otago bowling tournament	<i>Campylobacter</i>	8	13	EpiSurv	
2006	Cardrona Skifield	Norovirus	218		Appl Environ Microbiol	Hewitt J, Bell D, Simmons G, et al. (2007). Gastroenteritis Outbreak Caused by Waterborne Norovirus at a New Zealand Ski Resort. <i>Appl Environ Microbiol.</i> 73 (24):7853–7857
2006	School camp, Te Kuiti	<i>Campylobacter</i>	2	20	EpiSurv	
2007	School camp, Wellington	Gastro – unknown cause	96		NZPHSR	https://surv.esr.cri.nz/PDF_surveillance/NZPHSR/2007/NZPHSR200712Dec.pdf
2007	Northland school	Gastro – viral unknown cause	17		NZPHSR	https://surv.esr.cri.nz/PDF_surveillance/NZPHSR/2007/NZPHSR200709Sept.pdf
2008	Springston	<i>Campylobacter</i>	5	39	EpiSurv	http://www.3news.co.nz/Springston-residents-forced-to-boil-water-after-E-Coli-outbreak/tabid/423/articleID/49229/Default.aspx
2008	South Canterbury youth camp	<i>Campylobacter</i>	2	13	EpiSurv	
2010	Golden Bay Holiday Park	Norovirus			Nelson Mail	http://www.stuff.co.nz/nelson-mail/news/3655382/Lessons-from-norovirus-episode
2010	Waiouru Commanders' Course	<i>Campylobacter</i>	1	15	EpiSurv	
2011	Runanga drinking-water supply	<i>Campylobacter</i>	4		NZPHSR	https://surv.esr.cri.nz/PDF_surveillance/NZPHSR/2012/NZPHSR2012Mar.pdf
2012	Darfield drinking-water supply	<i>Campylobacter</i>	29	138	J of Water and Health	http://www.iwaponline.com/jwh/up/wh2014155.htm
2012	Hawke's Bay camping ground drinking-water	<i>Campylobacter</i>	28		NZPHSR	https://surv.esr.cri.nz/PDF_surveillance/NZPHSR/2012/NZPHSR2012Sep.pdf
2012	Cardrona Hotel and water supplies	Norovirus	48	5	NZMJ	http://www.ncbi.nlm.nih.gov/pubmed/24362738
2013	Nelson Lakes Scout camp	Gastro – unknown cause		13	EpiSurv	
2016	Havelock North	<i>Campylobacter</i>		5,500	DIA	https://www.dia.govt.nz/Government-Inquiry-into-Havelock-North-Drinking-Water

Relevant terminology

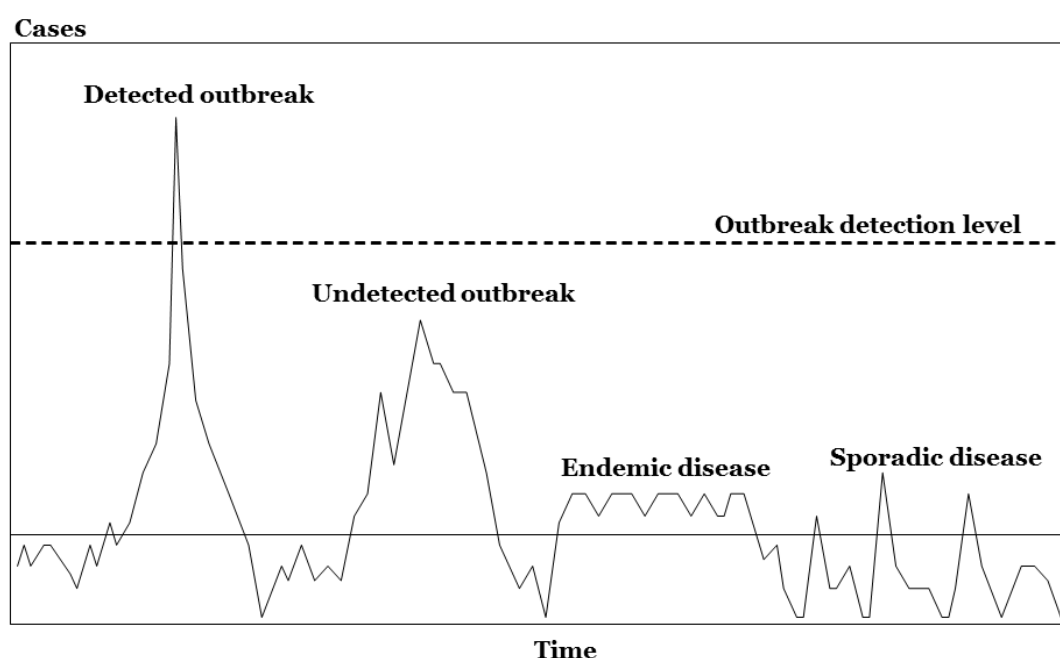
Outbreak is a term used in **epidemiology** to describe an occurrence of disease greater than would otherwise be expected in a particular time and place. It may affect a small and localised group or impact upon thousands of people across an entire continent. Two linked events of a rare infectious disease may be sufficient to constitute an outbreak. The outbreak detection level is determined by epidemiologists on the basis of their knowledge of the disease under consideration. Outbreaks may also refer to **epidemics**, which affect a region in a country or a group of countries, or **pandemics**, which describe global disease outbreaks.

The disease incidence rate is usually reported as the number of cases per 100,000 people per annum. Sometimes **disease burden** is used (DALY – see section 1.6.2); this incorporates the duration of the illness and its consequences and gives a better idea of how serious the outbreak may be. For example, a norovirus infection may last one or two days, but cryptosporidiosis may persist for more than two weeks.

- 1 **Sporadic disease:** A *sporadic disease* is one that occurs only occasionally in a population (ie, normally absent and unpredictable).
- 2 **Endemic disease:** An *endemic disease* is one that is always present in a population, with a predictable resolution or in a predictable way, with no external inputs needed.
- 3 **Epidemic disease:** An *epidemic disease* is a disease that many people acquire over a short period (ie, with suddenly increasing incidence).

Figure 1.1, amended from Frost et al 2003 by Craun et al 2004, illustrates the difference between outbreaks of disease (epidemic) and endemic or sporadic disease occurrences. Figure 1.1 shows there will be an underlying disease incidence below the reporting level.

Figure 1.1: Epidemic versus endemic/sporadic disease



1.1.4 The cost of providing potable drinking-water

Water that complies with the DWSNZ should be safe to drink. Since 1995 a number of attempts have been made to determine how much it will cost to upgrade all New Zealand drinking-water supplies to enable them to comply with the DWSNZ.

Two classes of expenditure must be considered:

- CAPEX – the capital expenditure required to provide treatment facilities that are capable of delivering compliant water
- OPEX – the cost of operating the water supply system and monitoring its performance. Note that this should (but doesn't always!) include maintenance.

Prior to 2000, Local Government NZ (LGNZ) made attempts to estimate these costs for local authority operated supplies, but found it difficult to obtain adequate data.

Prior to the passage of the Health (Drinking Water) Amendment Act in 2007 the Ministry of Health sponsored two major studies on the costs of providing treatment plants capable of providing potable drinking-water:

- in 2001 Beca Steven estimated the costs as \$269.50 to \$290.40 million (Beca 2001)
- in 2004 Roseveare and Yeabsley of OMS (OMS 2004) estimated the:
 - Capex as \$329.8 million
 - Opex as \$4.3 million per year.

The authors noted the wide error band of the estimates. The uncertainties arise from:

- the unknown number of small water supplies that are not operated by local authorities and are not on the Register. Some 1500 of these were registered, but many more were thought to exist
- the variable standard of the existing facilities. Although many were well-maintained and serviceable, a significant number were inadequate or very poorly maintained and would be expensive to bring up to a serviceable standard.

It is interesting to note that the US 1996 SDWA Amendments mandated that information about treatment technology performance and affordability be developed for small systems (<10,000 population). Affordability criteria (for the annual cost of drinking-water) are based on a threshold of 2.5 percent of the median household income (quoted from USEPA 2003).

The OECD (2011) notes that the full magnitude of the benefits of water services is seldom considered for a number of reasons. Non-economic benefits that are difficult to quantify but that are of high value to the concerned individuals and society, ie, non-use values, dignity, social status, cleanliness and overall wellbeing, are frequently under-estimated.

1.1.5 The benefits of potable drinking-water supplies

OMS (2004) estimated the direct annual benefit of illness avoidance by controlling waterborne disease in New Zealand at \$13 million to \$37 million a year on the basis of the notified waterborne enteric disease data of 18,000 cases in 1999 (the last full year of data available at the time) (assessed as costs foregone).

The data from 1986 to 2004 were later systematically reviewed by Ball of ESR in 2006. Ball concluded that the number of cases per year was at least 34,000, which would give a much higher benefit than that calculated by OMS.

OMS noted that an uncertain level of unknown additional benefits arose from:

- protecting the sanctity of the public drinking-water infrastructure (analogous to the sanctity of the blood bank)
- equality of access to a basic human right/need
- maintaining the 'New Zealand brand' in terms of our clean, green and secure environment in the eyes of the overseas community for food exports, and as a destination for immigration and tourism
- the benefits of the interventions included time-savings associated with better access to water and sanitation facilities, the gain in productive time due to less time spent being ill, health sector and patients' costs saved due to less treatment of diarrhoeal diseases, and the value of prevented deaths.

Table 1.4: Economic benefits arising from water and sanitation improvements

Beneficiary	Direct economic benefits of avoiding diarrhoeal disease	Indirect economic benefits related to health improvement	Non-health benefits related to water and sanitation improvement
Health sector	Less expenditure on treatment of diarrhoeal disease	Value of fewer health workers falling sick with diarrhoea	More efficiently managed water resources and effects on vector bionomics
Patients	Less expenditure on treatment of diarrhoeal disease and fewer related costs Less expenditure on transport in seeking treatment Less time lost in seeking treatment	Value of avoided days lost at work or at school Value of avoided time lost of parent or carer of sick children Value of loss of death avoided	More efficiently managed water resources and effects on vector bionomics
Consumers			Time savings related to water collection or accessing sanitary facilities Labour saving devices in the household Switch away from more expensive water sources Property value rise Leisure activities and non-use value
Agricultural and industrial sectors	Less expenditure on treatment of employees with diarrhoeal disease	Less impact on productivity of ill-health of workers	Benefits to agriculture and industry of improved water supply, more efficient management of water resources – time saving or income generating technologies and land use changes

Hutton and Haller (2004) summarised for WHO the benefits of potable drinking-water supplies, see Table 1.4, but noted that the intangible and unforeseen benefits often outweigh the direct benefits of disease reduction.

In another New Zealand study the Wellington Regional Council has estimated the cost of waterborne illness per affected household to be \$5,000 (WRC 1998), based on a household size of three persons, and period of illness of 2.5 weeks. Using Hamilton as an example (160,000 people), the cost of illness of a cryptosporidiosis outbreak in drinking-water could be estimated at \$109 million comprising \$80 million in cost of illness affecting 30 percent of the city and \$28.8 million due to a 0.025 percent mortality rate amongst those infected (12 people). Applying US figures, the cost of averting behaviour (hauling safe water, boiling water and/or purchasing bottled water) as a result of an outbreak of waterborne disease, again relating to Hamilton, is estimated at \$14.8 to \$46.8 million per month (Harrington et al 1985) who surveyed a community in Pennsylvania, USA which experienced a giardiasis outbreak in 1983). Averting behaviour expenditures were estimated for each household at US\$153 to \$483 per month (converted to NZ\$278 to \$878 at NZ\$/US\$0.55, for 53,300 households in Hamilton).

A further saving arises because consumers do not need to install any supplementary treatment device such as point-of-use (POU) equipment in any New Zealand water supply that complies with the DWSNZ and has a good Grading. Consumers that choose to install such equipment need to be careful that they do not introduce health concerns through improper use or maintenance, such as allowing bacteria to grow in the equipment that removes chlorine. See Chapter 19: Small, Individual and Roof Water Supplies, section 19.3.4 for further information.

Further savings arise because purchase of bottled water is unnecessary. It should also be noted that New Zealanders spent \$26,000,000 on bottled water in 2004, including coolers (G Hall, Corporate Water Brands, pers comm). At least some of this can be taken as the cost of a lack of confidence in public water supplies. Tap water quality in Tokyo is strictly regulated and advanced water treatment techniques such as ozonation have been widely introduced, with tap water quality attaining the highest level in the world. However, a 2013 consumer report indicated that only 49% of people in Tokyo drank tap water. Surveys have revealed a lack of knowledge about tap water regulation, with water suppliers needing to improve communication with citizens about safety and selection of tap water as drinking water.

LECG (2010) concluded a net economic benefit to New Zealand of \$134 million would be achieved by requiring large water suppliers to comply with both the bacteriological and protozoal determinands; a net economic benefit is also expected if medium supplies comply with both. The economic benefits to New Zealand for minor, small and neighbourhood supplies complying with both would need to be considered on a case by case basis. The cost of compliance was estimated by CH2M Beca (2010).

Dupont and Jahan (2012) examined factors that explained consumer spending on tap water substitutes using information from a national survey undertaken with a representative set of Canadian respondents. They developed a model to predict the percentage of households that undertook such spending for the purpose of reducing perceived health risks from tap water consumption. Using results from the model they estimated the magnitude of defensive expenditures to be over half a billion dollars (2010 US\$) per year for Canada, as a whole. This is equivalent to approximately \$48 per household per year or about \$19 per person per year. Residents of Ontario, the province in which an *Escherichia coli* incident took place in 2000, had the highest willingness-to-pay of approximately \$60 per household per year.

Darfield

The Canterbury town of Darfield (population 1790) experienced an outbreak of campylobacteriosis in August 2012 where it is estimated that 413 people became ill due to faulty chlorination of the water supply. A sensitivity analysis based on the lowest and highest plausible estimates of campylobacteriosis cases identified ranges of total monetised costs of \$308,592–\$536,401, 871 days off school and 0.93–1.31 DALYs. From: Sapere Research (2013).

Havelock North

A campylobacter outbreak occurred in Havelock North in 2016 (see Table 1.3). The MoH commissioned a report to determine the costs of outbreak (Sapere 2017).

Costs were separated into six broad groupings: local government, the business sector, central government, non-governmental organisations (NGOs), health/illness-related costs, and households. In addition, costs were distinguished by the following stages:

- investigation/diagnosis refers to the sourcing and confirmation of the outbreak (eg, expert reports, testing, planning and setting up response teams)
- reaction relates to costs that arose once the contamination was confirmed (eg, provision of bottled water, communications and information provision and co-ordination costs, welfare teams)
- remedial covers costs related to actions to 'make right' the water supply (treatment, engineering costs, further testing, etc)
- consequential describes costs that arise because of the outbreak (eg, filtered water stations, safeguards, and inquiry related costs)
- residual are costs that are ongoing such as monitoring, testing, rates rebates, information campaigns, and costs to respond to ongoing inquiries as to the safety of the water.

Total economic costs associated with the outbreak were estimated to be \$21,029,288. The vast majority of costs relate to household inconvenience due to having to boil water, buy bottled water, and taking time off from normal activities during the outbreak. This is a function of the large number of households affected (5,088) and the relatively high costs per household of around \$2,440.

An ESR presentation in 2019 stated that:

- scientists believe that the *Campylobacter* strains that caused the Havelock North outbreak were extremely virulent
- it is possible that people only needed to ingest 10 *Campylobacter* cells to become infected
- sheep defecate 865 g of faeces per day
- there are 3.3 million *Campylobacter* per gram of sheep faeces
- to contaminate Havelock North's water supply for one day only 70 g of faeces would need to have entered the drinking water reticulation system
- Havelock North residents would only have needed to drink 300 mL of water per day to become ill.

1.2 Ministry of Health public health protection strategy for drinking-water 1993–1995

1.2.1 Strategy development

The purpose of the Ministry of Health (MoH) strategy for drinking-water, formally adopted by the Director-General of Health in 1995, was to develop and apply the necessary tools for the implementation of the policy for drinking-water management.

From 1993 to 1995 the MoH developed an initial strategy to protect the public health safety of drinking-water. The goal of the MoH drinking-water policy was to achieve a high standard of drinking-water quality and management in New Zealand by promoting the understanding and application of the principles of public health safety by drinking-water suppliers and the general public. The development and implementation of this strategy are outlined below.

To develop its public health protection strategy for drinking-water, the MoH developed:

- goals and objectives for public health protection of drinking-water
- assessed whether the desired goals and objectives were realistic and achievable
- assessed the tools available for implementing the strategy:
 - which tools are currently in use?
 - what new tools are required?
 - would they work?
 - what were their strengths and weaknesses?
 - whether their performance could be enhanced by designing them to work synergistically
 - whether there was statutory authorisation for their use
- planned an integrated strategy by:
 - deciding which tools were needed to provide adequate protection for drinking-water quality
 - ascertaining how to design the tools to ensure that they reinforced one another in use
 - preparing a schedule of objectives for developing and implementing the tools.

The programme was designed to get the already-existing tools into operation as soon as possible and concurrently to:

- develop an overall strategy and a notional timetable for implementation
- redesign the already-existing tools to work better together to achieve the desired goals
- develop new tools as required.

1.2.2 Outline of the strategy

The Ministry of Health's drinking-water strategy from 1993 to 1995 involved:

- 1 development of performance standards on all aspects of management of drinking-water quality
- 2 development of standards of competence for health officers and Medical Officers of Health working with drinking-water in order to achieve consistent national standards
- 3 development and application of an integrated set of tools for promoting the provision of potable, wholesome drinking-water supplies
- 4 provision of information to the public on public health issues concerning drinking-water and the quality of community drinking-water supplies
- 5 promotion of public health issues concerning drinking-water to the public
- 6 promotion of self-management by the water supply industry
- 7 promotion of the use of quality assurance management techniques by water supply authorities, including adequate documentation of management procedures, monitoring procedures and contingency plans
- 8 provision of the electronic database Water Information, New Zealand (WINZ) to provide for the recording of all aspects of drinking-water supply performance and enable the assessment and reporting of improvement in performance
- 9 preparing for consultation on legislation to strengthen the implementation of the strategy
- 10 implementation of the overall strategy by a 'ratchet' process that improves performance in 'digestible' steps in one area and to facilitate advance in another area where progress had previously been difficult.

1.2.3 Planned milestones

- Obtain a clear understanding, by the end of 1996, of who will take responsibility for each of the various categories of community drinking-water supplies.
- Achieve implementation, by the end of 1997, of a programme of self-monitoring by the water suppliers, audited by health agencies, in 95 percent of all community drinking-water supplies.
- Achieve informed community discussion and decision-making on public health safety issues on drinking-water by the end of 1997.
- Achieve potable drinking-water in:
 - 95 percent of all large community drinking-water supplies (large = over 500 population supplied) by the end of 1996
 - 90 percent of all small community drinking-water supplies (small = 25 to 500 population supplied) by the end of 1998.

These targets are now for population groups rather than supplies.

1.2.4 Desired outcomes

- Adequate and effective monitoring of the quality of drinking-water supplies by suppliers.
- Sufficient knowledge and awareness of public health issues for the public to enable their effective participation in decision-making about public health issues relating to community drinking-water supplies.
- Competent health officers assessing the quality of water supplies to a consistent standard throughout the country.
- Improved public health safety standards for community and private drinking-water supplies.
- An effective statutory basis for the public health protection of drinking-water supplies.

1.2.5 Promotion of awareness of public health issues related to drinking-water

This was achieved by publication of reports on the public health grading of community drinking-water supplies and on the presence of determinands of public health concern found in the supplies (Priority 1 and 2 determinands) commenced in the *Register of Community Drinking-water Supplies in New Zealand* in 1993 and immediately attracted media attention.

Copies of the *Drinking-water Standards for New Zealand 1995*, the *Guidelines for Drinking-water Quality Management in New Zealand 1995* and the *Register of Community Drinking-water Supplies in New Zealand* (which was originally published approximately twice a year), were placed in every public library in the country to ensure that authoritative information on drinking-water quality management was freely available.

1.2.6 Outputs achieved by 1995

A number of the planned outputs were achieved or were well advanced in the first three years.

- Publication of the public health grading, together with drinking-water sources, of treatment plants and distribution zones commenced at the end of 1993.
- The 1984 *Drinking-water Standards for New Zealand* were revised by the end of 1994 and published in 1995.
- Most large community drinking-water supply treatment plants had been graded by the end of 1994.
- Standards for drinking-water data and data transfer were in place by mid-1994.
- New regulations for drinking-water quality management had not been achieved by 1995, but a discussion paper on the need for drinking-water legislation was in preparation.

1.3 Strategy development 1995–2000

1.3.1 Consultation

In 1995 a public discussion paper⁵ on the introduction of the Ministry's 1994 policy was published and public meetings on it were held in the four main centres in association with the NZWWA.

Based on the feedback from the 1995 paper a further discussion paper⁶ was produced in 1998 which reviewed all New Zealand legislation relating to drinking-water and outlined options for consolidating the legislation. This underwent consultation similar to that held on the 1995 paper, with similar results.

⁵ Drinking-water public health issues – a public discussion paper. MoH, Wellington, March 1995. 67 submissions were received representing the views of 101 agencies and groups. There was unanimous agreement that:

- 1.01 safe drinking-water is a key requirement for public health
- 1.02 all persons should have the right to expect that any water which they draw from a tap was safe to drink unless they were specifically informed to the contrary. This was considered especially important in premises handling food and to be particularly important for tourism, and travellers. It was considered that there was a need for signs in hotels, camps, farmstays etc where the water does not meet the Standards
- 1.03 the legislation relating to drinking-water is outdated, fragmented, inadequate and in need of revision, integration and cross-referencing. Over 36 Acts and Regulations are involved. In these, reference is made to 'acceptable', 'pure', 'wholesome', 'potable', or 'safe', water, etc; what these terms mean is rarely defined. All submissions on this subject recommended that the definitions of these terms should be standardised throughout the legislation
- 1.04 any legislative revision should remove gaps, produce consistency and remove conflict between the various Acts, Regulations and Bylaws which relate or refer to drinking-water quality, especially the Local Government Act 1974, the Rating Powers Act 1988, the Health Act 1956, the Resource Management Act 1991, the Water Supplies Protection Regulations 1961, the Building Act 1991 and the model Bylaws
- 1.05 compliance mechanisms and penalties should be effective and of equivalent severity to those in the Resource Management Act 1991 and the Health and Safety in Employment Act 1992
- 1.06 the Ministry of Health should be the lead organisation in the national management of drinking-water quality, with territorial authorities having a key role in the enhancement of drinking-water quality control
- 1.07 the Ministry of Health should be statutorily empowered to promulgate drinking-water standards
- 1.08 the Ministry of Health should be statutorily empowered to carry out the public health grading of drinking-water supplies
- 1.09 the respective roles, relationships and responsibilities of the various agencies and statutory officers involved in drinking-water quality management (principally the designated officers of the Ministry of Health and the TA's officers concerned with each of the supply, regulation and planning functions) need to be more clearly defined in the legislation. This includes defining the responsibility for each of water supply provision, monitoring, surveillance, audit etc
- 1.10 the public has a right to know about the quality and safety of drinking-water supplies and all information about these should be publicly available.

⁶ Review of the Water Supplies Protection Regulations 1961 (Review of Regulations made under the Health Act 1956) – a discussion document. MoH (Wellington), February 1998.

1.3.2 Inclusion of protozoa in the DWSNZ

Prior to 1990, the focus of waterborne disease prevention was on bacterial pathogens and much work was in progress to determine whether faecal coliforms (thermotolerant coliforms, enterococci or *Clostridium* spp) were the best indicators of the presence of faecal contamination. Work was also in progress to distinguish between organisms of human and animal origin because it was thought that animal organisms would not be pathogenic to humans. In the early 1990s it became evident that *Giardia* was a significant emergent waterborne disease in New Zealand. Consequently public health management of *Giardia* and *Cryptosporidium* was addressed in the 1995 and 2000 DWSNZ. Because of the difficulty of monitoring these protozoa directly, control in the 1995 and 2000 standards was by specifying turbidity (as a surrogate for particle counts) and filter pore size.

1.3.3 Human resource development

Assessment of the results of the first round of drinking-water supply grading carried out after public health grading was introduced in 1993 showed that the level of competence of the DHB health protection officers in assessing the performance of drinking-water supplies was very uneven. For effective administration of drinking-water quality management legislation it would be essential that the assessment process is carried out to a consistently high level of competence.

To prepare for the needs of the proposed legislation, the Ministry sponsored the establishment of a NZQA diploma in drinking-water assessment to provide appropriate training for HPOs in drinking-water supply management and operation, complemented by training in the legal requirements relating to their water supply duties. In addition, arrangements were made for the water HPOs to obtain IANZ accreditation to ISO/IEC 17020 specifications for inspection and assessment. Drinking-water assessment units (DWAUs) were set up in the participating DHBs. These were accredited by IANZ as inspection bodies with the officers who were to be appointed as DWAs after the legislation was promulgated, being designated as approved signatories for the DWAUs and authorised to use the IANZ logo on reports on the water supply assessments that they had been accredited to perform.

1.3.4 DWSNZ 2000

The 1995 DWSNZ were revised and finally re-issued in 2000 with the assistance of the Expert Committee on Drinking-water Quality. The main changes involved:

- replacing faecal coliforms as the indicator of faecal contamination to *E. coli*
- including *Cryptosporidium* in the protozoal compliance section. In the decade after 1995 the understanding of the public health importance of protozoa in drinking-water increased rapidly and the importance of *Cryptosporidium* as a major new waterborne pathogen that was resistant to conventional disinfection procedures or practices rapidly overtook that of *Giardia*. The scientific understanding of *Cryptosporidium* management advanced with extreme rapidity and by 2000 it became necessary to update the 1995 DWSNZ to incorporate the new knowledge. *Cryptosporidium* was selected as the representative protozoan because it is the most difficult to control in drinking-water

- introducing monitoring requirements for ozone and chlorine dioxide disinfection to meet the protozoal requirements, and removing the C.t tables for *Giardia* inactivation using chlorine
- the use of Bayesian statistics to guide the derivation of monitoring frequencies and acceptable transgression rates
- updating the MAVs based in the 1998 revision of the 2nd edition of the WHO *Guidelines for Drinking-water Quality*
- including PMAVs for cyanotoxins.

1.4 Strategy development 2000–2005

1.4.1 Consultation

In 2000 consultation was held in conjunction with NZWWA on the procedures that had been developed by ESR for the Ministry on Public Health Risk Management Plans (PHRMPs – now known as Water Safety Plans) for drinking-water supplies and on the need to update the Public Health Grading protocols. The philosophy behind the WSP was generally accepted. Proposals were made to include the WSP as part of the grading process, but it was decided to hold this over until there was more experience with the use of WSPs.

1.4.2 Water safety plans

The limitations of the historical approach to drinking-water quality management by the quality control (QC) procedure of assessing compliance with a product quality standard (the DWSNZ) had become evident by 2000.

Although the QC approach established whether the drinking-water quality targets had been met, this occurred only after the event. Also, because bacterial tests then took two days to complete, identification of a contamination event did not occur until two days after the event. The use of a water safety plan (WSP) for a water supply was seen as a way of introducing quality assurance (QA) procedures into drinking-water quality management. The publication of the NZ Guidelines on the Preparation of PHRMPs (Ministry of Health 2001)⁷ was followed by the publication of Chapter 4 on Water Safety Plans in the WHO *Guidelines on Drinking-water Quality* (3rd edition, 2004). Following the WHO publication the use of PHRMPs for drinking-water supplies (called water safety plans by WHO) has become an internationally accepted procedure. WHO has used New Zealand DWAs to provide training in water safety plans to the Pacific Island countries.

⁷ See *New Zealand Drinking-water Safety Plan Framework* – Ministry of Health (2018).

The stages in the development of a WSP are:

- identification of what is intended to be achieved (the target, eg, compliance with the DWSNZ)
- identification of the factors that could impede the achievement of the target (the risks). This includes identification of the financial and technical resources required to achieve the target, both the set-up and ongoing operational requirements
- identification of the ways in which the risks could be overcome (managed). This includes identification of the necessary financial and technical resources
- identification of the relative magnitude of the risks and ranking of the priorities for dealing with the risks, taking into account their importance and the relative ease of management
- development of contingency plans for managing unusual but critical perturbations of normal operation (eg, floods, droughts, power cuts, accidents to key personnel)
- completion of a schedule for managing the risks (a three- to five-year timetable)
- implement the WSP
- monitor, and review the WSP implementation performance, revise if necessary.

The water safety process can form the basis of a complete drinking-water quality management programme.

The steps along the pathway of using the WSP as the basis of a programme for achieving the target of a supply that delivers an adequate volume of water that is safe to drink are:

- 1 completion of a WSP for the supply
- 2 optimisation of the operation and management of the existing supply process
- 3 establishment of a programme for monitoring the performance of the water supply system to verify progress
- 4 preparation of an improvement schedule for the supply, based on the information in the WSP
- 5 preparation of a design report for upgrading the supply, if the target cannot be achieved (an engineer's report).

1.4.3 Legislative development

Building on the recommendations from the 1995 and 1998 public discussions on proposals for strengthening the drinking-water quality management sections of the Health Act 1956, Cabinet instructed the Ministry of Health in November 2000 to prepare a Health Act Amendment Bill which would provide a statutory framework for the non-regulatory interventions that were currently operating. The amendment was to strengthen and improve the existing legislation by:

- 1 providing assurance that a sector, with assets measured in the billions of dollars and which is fundamental to economic development (including the tourism sector), would be adequately managed
- 2 assisting local government to discharge their statutory duty “to improve, promote and protect public health”
- 3 placing duties on drinking-water suppliers to take all practicable steps⁸ to comply with the drinking-water standards (and various other duties and powers ancillary to that)
- 4 providing a statutory framework for the promulgation of drinking-water standards
- 5 putting duties on the general public not to contaminate drinking-water supplies
- 6 requiring drinking-water suppliers to introduce and implement water safety plans
- 7 providing for officers designated by the Ministry to act as assessors to verify:
 - compliance with the DWSNZ
 - the standard and implementation of water safety plans
 - the competence of water supply staff carrying out process and field analyses
- 8 requiring designated assessors to have their competence accredited by an internationally recognised conformance accreditation agency
- 9 providing for appropriate record-keeping and publication of information about the compliance of the supply with the Act.

1.4.4 Development of the DWSNZ 2005

Subsections 1.4.4.1 to 1.4.4.5 discuss the main changes from the 2000 DWSNZ. The DWSNZ 2005 maintained the two principal components:

- the water quality specification (standard), which defined the Maximum Acceptable Values (MAVs) at which the risk of disease from drinking the water is negligible. A new concept, operating requirements, was introduced where monitoring of a MAV was impracticable
- the compliance specifications, which define the checks (and their frequencies) that are to be taken to demonstrate compliance with the DWSNZ.

⁸ All practicable steps, in relation to the achievement of any particular result, means all steps to achieve that result that it is reasonably practicable to take in the circumstances, having regard to the:

- a) nature and severity of the harm that may be suffered if the result is not achieved, and
- b) current state of knowledge about the likelihood that harm of that nature and severity will be suffered if the result is not achieved, and
- c) current state of knowledge about harm of that nature, and
- d) current state of knowledge about the means available to achieve that result, and about the likely efficacy of each, and availability and cost of each of those means.

1.4.4.1 Introduction of the log credit approach

Because the methods available for identifying *Cryptosporidium* were not suitable for routine monitoring, and there appeared to be no suitable indicator organisms, it became necessary to improve the surrogate methods used to manage the public health risk. This was done by improving the performance of treatment processes in removing or inactivating *Cryptosporidium* oocysts. This stimulated the introduction of quality assurance methodology for drinking-water supply operational management, which culminated in the development of Public Health Risk Management Plans (now known as Water Safety Plans).

The risk of infection from drinking-water contaminated by waterborne protozoa is affected by the:

- concentration of *Cryptosporidium* oocysts or other protozoal cysts in the raw water
- extent to which (oo)cysts are inactivated or removed by the treatment processes.

To take account of the additive effect of a series of treatment processes on the removal of protozoa, log credits are used, *Cryptosporidium* being used as the reference organism. The log credit for a treatment process is the logarithm of the percentage of the protozoa the process can remove or inactivate. The cumulative effect of successive treatment processes can be calculated by adding the log credits of all the qualifying processes in use. The cumulative effects cannot be added when the removal is expressed as a percentage.

1.4.4.2 UV disinfection

Much work was done internationally on improving the understanding of the use of UV irradiation for inactivating *Cryptosporidium*. Originally UV was thought to be ineffective, because the oocysts appeared visually to be unchanged by exposure to UV. Development of means of measuring the extent of inactivation of the oocysts and measuring their infectiousness, combined with genotyping led to a significant increase in the understanding of control methods and demonstrated that UV was much more effective than initially thought.

UV will also control bacteria, but, like ozone, leaves no disinfectant residual.

1.4.4.3 Cyanobacteria

Prior to 2000, cyanobacteria were not considered a major problem in New Zealand surface waters. Outbreaks were few and far between and confined mainly to standing waters such as ponds and lakes. Since about 2000 the situation changed and cyanobacteria became much more prevalent, including a major outbreak in the Waikato River. Also it was realised that the public health concern was not the cyanobacteria themselves but the cyanotoxins that they produced.

Cyanobacteria produce a range of toxins similar to those found in toxic shellfish. Thus the control measures had to be based on the management of the toxins at least as much as the organisms. In addition to the planktonic cyanobacteria in the water mass, pads of benthic cyanobacteria have also become a problem and have caused a number of dog deaths. It was considered prudent to develop management techniques including action levels for cyanobacteria and cyanotoxins in drinking and recreational waters.

1.4.4.4 Small water supplies

Before 2005 the development of drinking-water standards was largely targeted to the management of water supplies serving populations greater than 500. Annual reviews of drinking-water quality have shown that the smaller supplies consistently perform less well than larger supplies. Also, the costs of monitoring water quality are relatively small per head of population when spread over a large community, but excessive when spread over a small number of people. Between 2000 and 2005 major consultations and discussions were held to try to improve the situation for small supplies, so drinking water standards based on risk management planning rather than formal compliance with water quality standards were developed for use in the 2005 DWSNZ.

1.4.4.5 Tankered drinking-water

In small unreticulated drinking-water supplies, especially ones in which roof water provides a significant proportion of the available water, it is almost inevitable that some portion of the water will be provided by tankered supplies.

It was considered necessary to provide for the management of the quality of this tankered drinking-water because there was anecdotal evidence that some tankered water deliveries were of dubious quality, due to use of dirty tankers or filling them from other than town supply hydrants.

1.4.5 Development of the drinking-water assistance programme

By 2003 it was evident from the annual review of drinking-water quality management that the improvement in water supplies due to the implementation of the 1993 policies had reached the point of diminishing returns and had reached a plateau. Larger supplies were substantially complying with the DWSNZ, but a number of the smaller supplies did not comply.

To ascertain the reasons for the non-performance of the smaller supplies, the Ministry sponsored surveys of some 120 smaller supplies to ascertain what these suppliers considered to be the major impediments to the improvement of their performance.⁹ This was supplemented by sixteen regional public meetings from Whangarei to

⁹ NZWWA/NZWERF. 2002. New Zealand Small Water Systems Survey (Report to the MoH) Wellington.

Invercargill.¹⁰ The principal impediment to compliance with the proposed legislation was seen as lack of technical training of the operators and the availability of technical information. This was considered by the small suppliers to be even more important than the costs that would be incurred in complying. Many of these suppliers did not know how to effectively manage the use of the facilities that they already had.

During the government's Infrastructure Stocktake (aimed at identifying the key utilities required to underpin the economic well-being of New Zealanders), drinking-water and waste management were identified as key utilities.

The need to improve the performance management of small supplies had been demonstrated by their poor performance recorded in the annual reviews of drinking water quality and by the responses of small communities to the consultation rounds. By 2000 sufficient information was being gathered on the management needs of small communities to enable the management needs of the 20 percent of the population serviced by small drinking-water supplies to be addressed.

Planning to meet the needs for provision of technical information and training for operators of small supplies together with financial assistance where this could be demonstrated to be necessary commenced in 2001. As a result of the government's infrastructure stocktake, funding for assistance to underperforming drinking-water supplies was made available in the 2005 Budget.

1.5 Operational development of the drinking-water management programme 2005–2009

1.5.1 The Drinking-water Assistance Programme, DWAP

To meet both the technical and financial needs of the small suppliers that had been identified by consultation and planning in 2000–2005, the Drinking-water Assistance Programme (DWAP) was designed to have two complementary components: the Technical Assistance Programme and the Drinking-water Subsidy Scheme. Public health units have been appointed to implement the DWAP on behalf of the Ministry and is for water supplies serving between 25–5,000 people.

¹⁰ ESR. 2004. Report on regional consultation meetings for smaller and rural water supplies; FW0474. Meetings were held in Whangarei, Tauranga, Hamilton, Taupo, Palmerston North, New Plymouth, Gisborne, Napier, Masterton, Queenstown, Greymouth, Nelson, Invercargill, Balclutha, Timaru, Kaikoura.

a) The Technical Assistance Programme

The first component of the DWAP is a Technical Assistance Programme that provides advice and technical assistance to drinking-water suppliers. The Technical Assistance Programme assists suppliers to evaluate their supply, produce a WSP and optimise the performance of their existing facilities. Should the supply be incapable of complying with the DWSNZ after its performance has been optimised, the Technical Assistance Programme can assist with assessing the capital works needed to upgrade the supply so that it can meet its performance targets. The Technical Assistance Programme is available to any supply under 5,000 people.

b) The Subsidy Scheme

The Technical Assistance Programme is complemented by a Subsidy Scheme that administers the funds available to the DWAP for capital assistance. Eligibility and priority criteria were revised in 2010. Applications for subsidy are processed through the Sanitary Works Technical Advisory Committee (SAWTAC).

Applicants for the Subsidy Scheme must meet the criteria set out in *Applying for a Drinking-water Subsidy: Guidelines for applicants and district health board public health units* available on the Ministry of Health's website. For the Subsidy Scheme:

- \$10 million is available for allocation each year until 2015
- the scheme will pay up to 85 percent of costs (previously it was 95 percent)
- only those communities with a Deprivation Index of 7 and above are eligible
- the criteria clarify that asset replacement, maintenance, land purchase and applications from city councils are not eligible for subsidies
- an engineering review is required for subsidy applications that exceed \$1,000 subsidy per person for a water supply scheme.

Applications must be submitted to the Ministry of Health no later than 5 pm on 28 February of each year until 2015. Further information is available from public health units and on the Ministry of Health's website.

1.5.2 Legislation: The Health (Drinking Water) Amendment Act 2007 (Part 2a of the Health Act 1956 – the Act)

The Health (Drinking Water) Amendment Bill that was passed in 2007 contained a number of changes from the original proposals submitted to Cabinet in 2000, which are listed in section 1.2.2. These changes were either authorised by Cabinet before the Bill went to Parliament, or were recommended by the Select Committee. These included:

- tankers, ports and airports to be classified as drinking-water suppliers
- changes to the criteria for establishing whether the 'all practicable steps' criterion had been met
- addition of the new category of Rural Agricultural Drinking-water Supply to the list of categories of water supplies
- the requirement to assess whether an action required under the Act is affordable as part of the procedure for deciding whether all practicable steps have been taken to achieve a result required.

1.5.3 The 2008 revision of DWSNZ 2005

The amendment to the Act necessitated a number of changes to the DWSNZ 2005, including the need to develop a section on Rural Agricultural Drinking-water Supplies. The changes were published in the 2008 revision of the DWSNZ 2005 and became available as the Rural Agricultural Drinking-water Supply Guideline (Ministry of Health 2015). The introduction of the WSPs necessitated a number of minor adjustments to ensure compatibility with the Act.

Although the DWSNZ 2005 had been the result of a consensus among members of the Expert Committee on Drinking-water Quality, set up to advise the Ministry of Health, several submissions from small water suppliers necessitated major rewrite of section 10 (small supplies).

Water suppliers were invited to comment on the 2005 DWSNZ, resulting in the clarification of the other sections, particularly related to procedural matters in the protozoal compliance section. The opportunity was also taken to update the maximum acceptable value (MAV) tables based on the latest World Health Organization (WHO) information. All water suppliers that had commented on the 2005 DWSNZ were asked to confirm that their concerns had been addressed in the draft revision.

1.5.4 Tankered drinking-water supplies

Standards have been developed for use with different types of source water for tankered supplies. For operational guidance, the Tankered Drinking Water Carrier's Association has prepared *Guidelines for the Safe Carriage and Delivery of Drinking-water*. The initial draft was produced in conjunction with the New Zealand Water and Wastes Association, as a Code of Practice. The final version was published by the Ministry in 2008, as Guidelines (Ministry of Health 2008).

1.5.5 Development of specifications for Rural Agricultural Drinking-water Supplies (RADWS)

The DWSNZ 2005 revised (2008) are prescriptive standards developed to ensure potable drinking-water for the population's water supplies. Many of the criteria used in these standards are population-based and are appropriate for use in homogeneous reticulated communities such as towns where the principal purpose of the water supply is for drinking. However they do not meet the needs of the rural situation where the purpose of the water supply is more heterogeneous.

In rural communities a large proportion of the water supply may not be intended for drinking. The water may be used mainly for irrigation or stock watering. Treating all of this water to comply with the drinking-water standards may be pointless and unnecessarily costly. For this reason it was proposed that a Rural Agricultural category (RADWS) be developed in which only water intended to be drunk by humans will be required to meet the drinking-water standards.

This became available as the *Rural Agricultural Drinking-water Supply Guideline* (Ministry of Health 2015). This is also discussed briefly in Chapter 19.

1.5.6 Point-of-use and point-of-entry drinking-water treatment appliances standards

To facilitate the regulatory control over the performance of point-of-use (POU) and point-of-entry (POE) drinking-water treatment appliances, the documentation of the appliance needs to specify:

- a) what contaminants the appliance will control
- b) what contaminants the appliance will NOT control
- c) performance standards for control of the contaminants of concern
- d) a clear indication of when the appliance is no longer achieving its performance standards.

There are four relevant international standards that deal with POU and POE appliances:

- 1 AS/NZS 4983:1998 Water supply – Domestic type water treatment appliances – Performance requirements
- 2 AS/NZS 3497:1998) Amended Plumbing Requirements for POU and POE appliances
- 3 NSF/ANSI 53, and
- 4 NSF/ANSI 55.

Of these standards only AS/NZS 3497:1998 includes the documentation requirements specified above.

The technical performance specifications of AS/NZS 4983 need to be brought up to the standard of the specifications of NSF/ANSI 53 and NSF/ANSI 55 in order to ensure that the appliance will deliver water that complies with the DWSNZ.

1.6 Tools for promoting potable drinking-water supplies

1.6.1 Introduction

From 1992 to 1996 the Ministry of Health developed an integrated set of tools for improving drinking-water quality to protect public health. These tools were designed in such a way that they reinforce one another in use and included the:

- public health grading of community drinking-water supplies
- the 1995 *Drinking-water Standards for New Zealand*
- development of national drinking-water databases, eg, WINZ
- and publication of:
 - *Register of Community Drinking-water Supplies in New Zealand*
 - *Guidelines for Drinking-water Quality Management in New Zealand*
 - *Annual Reports on Quality of Drinking-water in New Zealand*.

Subsequently, the following new tools have been added:

- the introduction of water safety plans
- the introduction of drinking-water assessment and the training of personnel for this
- publication of the *Register of Recognised Laboratories*
- publication of the *Register of Drinking-water Assessors*.

Several of these tools have been updated since 2000, eg, the DWSNZ, the Guidelines, the Grading, and the WINZ software (now called Drinking-water Online).

The tools are designed to promote maximum interaction and mutual support between the various stakeholders, the public, the media, the drinking-water supplier, and the drinking-water assessor. Emphasis is on using risk management planning techniques to promote a quality assurance approach. This is complemented by a monitoring programme used as a final quality control that also acts as a feedback loop and provides a trigger for remedial action where this is necessary.

A description of the tools used by the Ministry of Health, and the way they interact, follows in sections 1.6.4 to 1.6.15.

1.6.2 Four tools used by the World Health Organization

The World Health Organization uses four approaches when considering health-based targets.

- 1 The tolerable burden of disease. This is called disability-adjusted life years (DALYs) which can be used to quantify and compare the burden of disease associated with different water-related hazards, taking into account varying probabilities, severities and duration of effects, regardless of the type of hazard (microbial, chemical or radiological) to enable the use of a consistent approach for each hazard. WHO has used DALYs to evaluate public health priorities and to assess the disease burden associated with environmental exposures, particularly for microbial hazards. The tolerable burden of disease is defined as an upper limit of 10^{-6} DALY (μ DALY) per person per year. This upper-limit DALY approximates a 10^{-5} excess lifetime risk of cancer (ie, 1 excess case of cancer per 100 000 people ingesting drinking-water at the water quality target daily over a 70-year period), which is the risk level WHO uses to determine guideline values for genotoxic carcinogens. See section 3 in WHO 2017 for further information.
- 2 Guidelines values. Guideline values for chemicals are based on individual chemical risk assessments. These are called maximum acceptable values (MAVs) in the DWSNZ.
- 3 Specified removal of hazards. These are usually expressed as log reductions. This approach has been adopted in the DWSNZ for protozoa.
- 4 Defined technologies. This usually involves use of validated treatment equipment such as UV disinfection, membrane and cartridge filtration.

1.6.3 The six guiding principles of drinking-water safety

The Australian Drinking-water Guidelines incorporate six well-established principles for potable drinking water. The principles were developed in 2001 by a working group comprising the World Health Organisation microbial pathogens expert group and the Medical Research Council of Australia.

Principle 1: A high standard of care must be embraced

Unsafe drinking water can cause illness, injury or death on a large-scale. All those involved in supplying drinking water (from operators to politically elected representatives) must therefore embrace a high standard of care akin to that applied in the fields of medicine and aviation where the consequences of a failure are similarly detrimental to public health and safety. Vigilance, diligence and competence are minimum requirements and complacency has no place.

Principle 2: Protection of source water is of paramount importance

Protection of the source of drinking water provides the first, and most significant, barrier against drinking water contamination and illness. It is of paramount importance that risks to sources of drinking water are understood, managed and addressed appropriately. However, as pathogenic microorganisms are found everywhere, complete protection is impossible and further barriers against contamination are vital.

Principle 3: Maintain multiple barriers against contamination

Any drinking water system must have, and continuously maintain, robust multiple barriers against contamination appropriate to the level of potential contamination. This is because no single barrier is effective against all sources of contamination and any barrier can fail at any time. Barriers with appropriate capabilities are needed at each of the following levels: source protection; effective treatment; secure distribution; effective monitoring; and effective responses to adverse signals. A “source to tap” approach is required.

Principle 4: Change precedes contamination

Contamination is almost always preceded by some kind of change and change must never be ignored. Sudden or extreme changes in water quality, flow or environmental conditions (for example, heavy rainfall, flooding, earthquakes) should arouse particular suspicion that drinking water might become contaminated. Change of any kind (for example, personnel, governance, equipment) should be monitored and responded to with due diligence.

Principle 5: Suppliers must own the safety of drinking water

Drinking water suppliers must maintain a personal sense of responsibility and dedication to providing consumers with potable water. Knowledgeable, experienced, committed and responsive personnel provide the best assurance of potable drinking water. The personnel, and drinking water supply system, must be able to respond quickly and effectively to adverse monitoring signals. This requires commitment from the highest level of the organisation and accountability by all those with responsibility for drinking water.

Principle 6: Apply a preventive risk management approach

A preventive risk management approach provides the best protection against waterborne illness. Once contamination is detected, contaminated water may already have been consumed and illness may already have occurred. Accordingly, the focus must always be on preventing contamination. This requires systematic assessment of risks throughout a drinking water supply from source to tap; identification of ways these risks can be managed; and control measures implemented to ensure that management is occurring properly. Adequate monitoring of the performance of each barrier is essential. Each supplier’s risk management approach should be recorded in a living WSP which is utilised on a day to day basis.

1.6.4 Drinking-water Standards for New Zealand

WHO (2017) considers the functions of surveillance and quality control are best performed by separate and independent entities because of the conflict of interest that arises when the two are combined. In this:

- national agencies provide a framework of targets, standards and legislation to enable and require suppliers to meet defined obligations
- agencies involved in supplying water for consumption by any means should be required to ensure and verify that the systems they administer are capable of delivering potable water and that they routinely achieve this
- a surveillance agency is responsible for independent (external) surveillance through periodic audit of all aspects of safety and/or verification testing.

The DWSNZ in 1995, 2000, 2005 and 2008 were based on the following principles.

1. The DWSNZ define the maximum concentrations of chemicals of health significance (MAVs) in water that, based on current knowledge, constitute no significant risk to the health of a person who consumes 2 L of that water a day over their lifetime (usually taken as 70 years).

Potable water is drinking-water that does not contain or exhibit any determinand to any extent that exceeds the MAVs specified in the DWSNZ (see the definition of 'potable' in section 69G of the Act).

The DWSNZ do not purport to specify a concentration of contaminant at which zero risk exists because a degree of uncertainty over the magnitude of the risk always exists. The datasheets in the Guidelines (vol 3) provide information on each determinand.

2. The DWSNZ give highest priority to health risks arising from microbial contaminants because they can lead to rapid and major outbreaks of illness. Control of microbial contamination is of paramount importance and must not be compromised in an attempt to correct chemical problems, such as disinfection by-product (DBP) formation.
3. The DWSNZ set priorities on how to ensure that, while public health is protected, scarce resources are not diverted to monitoring substances of relatively minor importance.
4. The DWSNZ set out to protect public health and apply only to health-significant determinands.

However, because the public generally assesses the quality of its water supply on aesthetic perceptions, guideline values for aesthetic determinands are also provided (DWSNZ section 2), although they are not part of the water quality standards.

Wholesome drinking-water is potable water that does not contain or exhibit any determinands that exceed the guideline values for aesthetic determinands in the DWSNZ (see the definition of 'wholesome' in section 69G of the Act). For more details, see chapter 18.

5. To demonstrate compliance with the MAVs, water suppliers need to follow the relevant sampling and testing programmes detailed in sections 4, 5 and 7 to 12 of the DWSNZ.
6. Where feasible, the sampling protocols are designed to give 95 percent confidence that no determinand in a supply has exceeded its MAV for more than 5 percent of the time.

The MAVs for micro-organisms are determined differently from those for chemicals.

- a) The MAV of a micro-organism is its concentration in drinking-water above which there is a significant risk of contracting a waterborne (enteric) disease.
- b) Because of the limitations of existing microbial technology, MAVs are not given for all micro-organisms of health significance (eg, all pathogens). Instead MAVs are given for the representative organisms *Escherichia coli* (*E. coli*) for the bacteria and *Cryptosporidium* plus *Giardia* (representing the protozoa).
- c) *E. coli* is used as an indicator of bacterial risk because it indicates the presence of faecal material and, therefore, the potential presence of pathogenic bacteria.
- d) There are no MAVs for viruses; water that meets bacterial and protozoal compliance is deemed to virologically satisfactory.

The DWSNZ also prescribe MAVs for the determinands of public health significance other than micro-organisms. These MAVs are the concentrations of determinands below which there is no significant risk to a consumer over a lifetime of consumption assessed at 2 litres per day.

MAVs for chemical determinands of health significance are given in Tables 2.2 and 2.3 of the DWSNZ. Because the relationship between cyanobacterial numbers and toxin production is highly variable, no attempt is made to develop MAVs for cyanobacteria, but they are developed for their cyanotoxins.

Wherever possible, the MAVs have been based on the latest WHO guideline values. WHO calls their guideline values provisional when there is a high degree of uncertainty in the toxicology and health data, or if there are difficulties in water treatment or chemical analysis. The DWSNZ adopt the same approach. Provisional MAVs (PMAVs) have also been applied to chemical determinands when the Ministry of Health has derived a MAV in the absence of a WHO guideline value. In terms of compliance with the DWSNZ, PMAVs are considered to be equivalent to MAVs.

Chemical MAVs are based on average values, and while a higher daily dose could be safe for a certain period, consumption of that dose for a lifetime is not expected to be safe. Average values are used for framing Regulations because provision cannot be made for all possible combinations of exposures that individuals may encounter; an exception is cyanide where the MAV has been established to protect consumers during short-term exposure following a significant spill of cyanide to a drinking-water source (see datasheet in the Guidelines). There is a short-term MAV for nitrate and nitrite as well, established to protect against methaemoglobinaemia in bottle-fed infants.

For carcinogenic chemicals, the MAVs set in the DWSNZ generally represent a risk of one additional incidence of cancer per 100,000 people ingesting the water at the concentration of the MAV for 70 years.

For most other chemicals, MAVs have been calculated using a tolerable daily intake (TDI) approach that identifies the dose below which no evidence exists that significant adverse effects will occur and that will represent no significant risk to a consumer from a lifetime of consumption of 2 L of the water per day. The derivations of the MAVs are explained in the datasheets in the Guidelines.

MAVs apply to water intended for human consumption, food preparation, utensil washing, oral hygiene or personal hygiene. Approximately one third of the daily average fluid intake is thought to be derived from food. The remaining water requirement must be met from consuming fluids. The criteria in the DWSNZ are applicable to all drinking-water except bottled water, which must comply with the Food Act 1981.

The WHO assesses determinands for which health concerns have been raised and has found many are unlikely to occur in drinking-water or occur at levels well below those at which toxic effects are observed. Datasheets for these determinands appear in the Guidelines.

The DWSNZ list the maximum concentrations of chemical, radiological and microbiological contaminants acceptable for public health in drinking-water. For community drinking-water supplies, the DWSNZ specify the sampling frequencies and testing procedures that must be used to demonstrate that the water complies with the DWSNZ.

The sampling frequencies are chosen to give 95 percent confidence that the medium to large drinking-water supplies comply with the Standards for at least 95 percent of the time. The larger supplies are required to monitor more frequently. The DWSNZ 1995 used classical statistics to derive the necessary monitoring frequencies, but the DWSNZ 2000 took advantage of more recent advances in the use of statistics in which monitoring frequencies are derived using the Bayesian approach (McBride and Ellis 2000). For further information, refer to the Appendix.

The DWSNZ do not describe how a water supply should be managed. This should be covered in the water safety plans. Water supply management is also discussed in the *Guidelines for Drinking-water Quality Management in New Zealand*.

The DWSNZ specify MAVs for more than 120 determinands. To minimise the number of determinands that have to be monitored routinely in any specific drinking-water supply but still maintain adequate safeguards to public health, the DWSNZ have grouped the determinands of public health concern into three priority classes, see section 1.6.10 and Table 1.5. The Appendix includes a discussion on how to handle 'non-detects' or 'less than values'.

The potential indicators of disease-causing organisms, micro-organisms characteristic of faecal contamination, are given the highest priority (Priority 1), in the DWSNZ because the public health implications of disease organisms in the water supply are almost always of greater concern than the presence of chemical contaminants, which are usually slower acting.

It can be seen that the top priority is given to identifying potential causes of infectious disease outbreaks. In an ideal world a screening test would be used that provides instant identification of the presence of pathogenic organisms in drinking-water. At present no such test exists. Until better tests have been developed, New Zealand, like the rest of the world, has to fall back on the use of indicator organisms to identify the probability that the water has been contaminated by excrement and, therefore, the possibility that pathogenic bacteria or viruses are present. Because of the practical difficulties in routinely enumerating infectious protozoa in drinking-water, surrogate methods have had to be used, based on checking that the water is from a safe source or has received a level of treatment that has a high probability of removing protozoal organisms.

Information on the supply-specific Priority 2 determinands, ie, those determinands in a drinking-water supply that are of public health concern, is published in the *Annual Review* (see section 1.6.12).

The MAVs in the DWSNZ apply to private and individual household drinking-water supplies as well as to community supplies. Because of the wide variation in the circumstances of individual supplies it is not possible to give explicit guidance on sampling strategies for individual supplies in the DWSNZ. Individual household supplies are discussed in Chapter 19 of these Guidelines. Advice on specific cases can be obtained from the drinking-water assessors.

Compliance with the DWSNZ demonstrates that a drinking-water supply is potable within the meaning of the Act. The DWSNZ:

- 1 specify bacteriological referee methods against which the methods used by individual laboratories have to be calibrated satisfactorily
- 2 require that laboratories carrying out compliance testing be approved for the purpose by the Ministry of Health
- 3 specify minimum remedial action needed in the event of the DWSNZ being breached.

1.6.5 Guidelines for Drinking-water Quality Management in New Zealand

The *Guidelines for Drinking-water Quality Management in New Zealand* (the Guidelines) provide more detailed information on the public health management of drinking-water and the properties of drinking-water determinands of public health concern than appears in the DWSNZ. They provide access to information on public health aspects of drinking-water to water supply personnel, health personnel and the general public. The original *Guidelines* were published in 1995 and were directed mainly at small supplies and some self-suppliers. The 2005 edition and subsequent revisions are directed at all water supplies.

The *Guidelines* provide background and supporting information for the DWSNZ and will be revised as necessary. The *Guidelines* contain:

- guidance and good management principles for community drinking-water supplies
- volume 1 includes the chapters. Chapters 1–5 are largely introductory and discuss risk management, and source water. Chapters 6–11 discuss compliance issues. Chapters 12–18 relate to operating and maintaining the supply. Chapter 19 covers small supplies
- the datasheets, in volume 2, describe how the criteria used in the DWSNZ were derived.

These datasheets also provide background information about each determinand including their sources, environmental forms and fates, typical concentrations either in New Zealand or overseas drinking-water supplies, processes for removing the determinand from drinking-water, analytical methods, health considerations, derivation of the MAVs for health significant determinands and Guideline Values for aesthetic determinands, and references for further reading. Datasheets for determinands of possible health and aesthetic significance and are included for general information.

1.6.6 Water safety plans

The introduction of public health risk management plans (PHRMPs – now known as Water Safety Plans) in 2001 marked the transition from drinking-water quality management procedures from purely quality control (monitoring compliance against product quality standards) to a combination of QC and quality assurance (QA). Prior to 2001 public health management of supplies relied largely on compliance monitoring of the quality of the water produced by individual water suppliers to check that it complied with the DWSNZ. While monitoring is always important, WSPs for drinking-water supplies provide the additional benefit of introducing management procedures that reduce the likelihood of contaminants entering supplies in the first place. By the time monitoring shows that contaminants are present, something has already gone wrong and a hazard is already present in the water. But identifying and managing risks should prevent hazards arising.

WSPs encourage the use of risk-management principles during treatment and distribution so that monitoring is not the only water quality management technique used thereby further reducing the risk of contamination.

To assist drinking-water suppliers to develop WSPs for their drinking-water the Ministry of Health produced 39 PHRMP Guides covering the system elements (eg, filtration, disinfection, water storage, distribution etc) that are most frequently found in drinking-water supplies. The model PHRMP Guides are available at <http://www.health.govt.nz/water> then select publications and Public Health Risk Management Plans ~ Reference Guides. WSPs are discussed in detail in Chapter 2: Management of Community Supplies.

The first item, How to prepare and develop public health risk management plans for drinking-water supplies should be read before using any of the PHRMP Guides because it explains the risk management process and how the different guides are intended to be used to build up a WSP for a particular water supply.

Subsequently, in 2005, simplified WSP procedures and multi-media training material were developed especially for use by small water supplies and published, together with related training CDs, as an integral part of the DWAP TAP.

All but the smallest community water supplies are required to prepare and implement a WSP (HDWAA section 69Z). The timetable for compliance with this requirement is set out in HDWAA sections 69C to 69F. Water supplies that are smaller than neighbourhood supplies (usually smaller than 25 persons) are not required to have WSPs unless specifically required to do so by the Medical Officer of Health.

The preparation of an approved WSP by a drinking-water supplier provides one way of demonstrating that all practicable steps have been taken to meet the requirements of the proposed drinking-water legislation (HDWAA section 69H), because it:

- identifies the nature and magnitude of public health risks inherent in the water supply process
- specifies what preventive and corrective procedures should be in place to manage/mitigate each risk
- identifies what will be done by the supplier to mitigate the risks
- identifies what the supplier is not able to do to mitigate the risks because of resource limitations.

1.6.7 Public health grading of drinking-water supplies

The grading of community drinking-water supplies is a voluntary system that has been in place in various forms since 1962. The current grading system was updated in 2003 to incorporate changes introduced by the *Drinking-water Standards for New Zealand 2000*. There is no requirement for a water supplier to participate in grading. If a water supplier chooses not to be graded, the supplier is recorded in the *Register of Drinking-water Supplies in New Zealand* as being ungraded.

In 2008, following the amendments to the Health Act 1956 that introduced a statutory compliance regime for drinking-water supplies, ESR Ltd surveyed water supply stakeholders to see if there was support for a new grading framework. The survey found that grading was still regarded by water suppliers as an important tool, and the purpose of providing a public statement of safety was still desirable. Stakeholders agreed however that the existing framework did not satisfactorily account for risk. It had no provision for water safety plans (WSPs), or for the requirements of the *Drinking-water Standards for New Zealand 2005 (revised 2008)*.

At the time of writing the consultation on revision of the Grading Framework had closed with submissions being analysed.

1.6.8 Drinking-water assessment

The role of the Drinking-water Assessors (DWAs) is to verify that that the requirements of the Health Act 1956 as they relate to drinking-water have been complied with. The DWAs are appointed by the Director-General of Health, and have the following set of tasks and their functions are set out in section 69ZL of the Act.

DWAs are located in District Health Board public health units and are accredited as authorised signatories. Maintenance and public access to a Register of Drinking-water Assessors is a requirement of the Act's section 69ZX. The Register can be accessed at: <http://www.health.govt.nz/water> then select legislation.

1.6.9 Monitoring

Assesses the extent to which a drinking-water supply complies with the DWSNZ at the time of monitoring.

Monitoring of the quality of a community drinking-water supply was made the responsibility of the drinking-water supplier in the DWSNZ 1995. Previously, under the DWSNZ 1984, monitoring had been carried out by the (then) Department of Health.

To demonstrate compliance with the DWSNZ, the Priority 1 and 2 determinands have to be monitored according to the protocols set down in the DWSNZ. The DWSNZ specify the minimum frequency of compliance monitoring. Water suppliers also conduct process control testing and quality assurance monitoring as part of their day-to-day management. Process control test results can be used for compliance monitoring if the procedure used complies with the requirements of the DWSNZ.

1.6.10 Surveillance

Surveillance requires a systematic programme of surveys, which may include auditing, analysis, sanitary inspection and institutional and community aspects. It should cover the whole of the drinking-water system, including sources and activities in the catchment, transmission infrastructure, treatment plants, storage reservoirs and distribution systems (whether piped or unpiped) (WHO 2017).

The definition of surveillance in the DWSNZ is: the process of checking that the management of drinking-water supplies conforms to the specifications in the Drinking-water Standards for New Zealand (DWSNZ); usually conducted by the public health agency. An example of surveillance is the process that results in a chemical determinand being assigned as a P2 (see next section).

The WHO Guidelines describe drinking-water supply surveillance as “the continuous and vigilant public health assessment and review of the safety and acceptability of drinking-water supplies”. This surveillance contributes to the protection of public health by promoting improvement of the quality, quantity, accessibility, coverage, affordability and continuity of water supplies (known as service indicators) and is complementary to the quality control function of the drinking-water supplier. Drinking-water supply surveillance does not remove or replace the responsibility of the drinking-water supplier to ensure that a drinking-water supply is of acceptable quality and meets predetermined health-based and other performance targets.

1.6.11 Identifying priority 2 and priority 3 determinands

Between 1995 and 2004, the Ministry of Health’s Priority 2 Chemical Determinands Identification Programme assessed drinking-water supplies to identify which chemical determinands needed to be assigned as Priority 2 determinands. Since then water suppliers have been responsible for identifying in their Water Safety Plan chemicals of health concern in their own water supplies as the drinking-water sections of the Health Act 1956 come into force for their supplies. The procedure, with advice to help identify determinands that might be of concern, is described in *Priority 2 and Priority 3 Chemical Determinands Identification Guide*, produced by ESR for the Ministry in 2015.

The *Guide* also includes recommendations for monitoring Priority 3 determinands, because no requirements for sampling Priority 3 determinands are contained in the DWSNZ. However, there are situations in which sampling for them is a necessary part of good public health risk management. For example, where a determinand is present at concentrations near the MAV in the source water, its concentration in the distribution zone may be reduced to a level less than 50 percent of the MAV by treatment. Changes in treatment efficacy could cause the determinand's concentration in the reticulated water to exceed 50 percent of the MAV.

Table 1.5: Examples of priority allocation in the DWSNZ¹¹

Priority	Example of determinands
<p>Priority 1 Applies to all community drinking-water supplies</p>	<p><i>Escherichia coli</i> (<i>E. coli</i>) <i>Giardia</i> <i>Cryptosporidium</i></p>
<p>Priority 2 Applies to determinands where there is good reason to believe that the substance is present in concentrations that present a potential public health risk (this priority is specific to the particular supply)</p>	<p>Chemical and radiological determinands that could be introduced into the drinking-water supply by the treatment chemicals at levels potentially significant to public health (usually greater than 50 percent MAV) eg, acrylamide monomer where low specification polyacrylamide is used as a coagulant aid. Chemical and radiological determinands of health significance that have been demonstrated to be in the drinking-water supply at levels potentially significant to public health (usually greater than 50 percent MAV) eg, arsenic and boron in geothermal areas. Micro-organisms (other than priority 1) of health significance which have been demonstrated to be present in the drinking-water supply</p>
<p>Priority 3 Applies to determinands not likely to be present in the supply to the extent where they could present a risk to public health</p>	<p>Chemical and radiological determinands of health significance which are not known to occur in the drinking-water supply at greater than 50 percent MAV. Micro-organisms of health significance which could be present in the drinking-water supply. Determinands of aesthetic significance that may occur in the drinking-water supply.</p>

1.6.12 Register of Community Drinking-water Supplies and Suppliers in New Zealand

The *Register of Community Drinking-water Supplies and Suppliers in New Zealand* is a requirement of the Health Act (s69J). It is a public document that provides easily accessible information about community water supplies and drinking-water carriers.

For each supply, the Register records:

- the name and address of the drinking-water supplier or carrier
- the source(s) of the supply
- unique codes for each component (to aid clear identification)
- when the supply was first registered
- category of the supply.

¹¹ The priority classification scheme was introduced to give guidance as to the relative public health concern relating to the many determinands of public health significance that are listed in the WHO *Guidelines for Drinking-water Quality*. A detailed discussion of the priority classes is given in the DWSNZ.

1.6.13 Annual Review of Drinking-water Quality in New Zealand

The *Annual Review of Drinking-water Quality in New Zealand* provides a public statement of the extent to which a community water supply (serving over 100 people) complies with the requirements of the Part 2A Health Act 1956.

Publication of an annual report is a requirement of the Director-General under section 69ZZZB. Annual reviews are available at <http://www.health.govt.nz/water> (then select publications).

1.6.14 Register of recognised laboratories

To be accepted by the Ministry of Health for the purpose of analysing samples for compliance with the DWSNZ, a laboratory must satisfy the Ministry that it:

- requires suppliers who send samples from community drinking-water supplies for analysis for the purpose of demonstrating compliance with the DWSNZ, to identify all such samples with the appropriate unique site identification code as listed in the current *Register of Community Drinking-water Supplies and Suppliers in New Zealand*
- has been recognised by an appropriate accreditation or certification authority as competent to perform those analyses for which acceptance by the Ministry is sought (this would involve accreditation to NZS/ISO/IEC 17025 [IANZ 2005] or equivalent). This includes IANZ accredited laboratories and laboratories recognised by IANZ as complying with Ministry of Health Level 2 Criteria (IANZ 2007)
- is operating appropriate quality assurance procedures
- is using bacteriological methods that have been calibrated against the referee methods specified in the DWSNZ. Laboratories conducting chemical tests for compliance purposes may use the test methods for which they have been assessed by IANZ and found to be competent to perform
- is actively engaged in on-going inter-laboratory method-comparison programmes to compare the results of their analyses of the determinands for which they wish to be accepted by the Ministry with analyses on those determinands carried out by other laboratories accepted by the Ministry.

Other requirements may be added from time to time.

The Register of Recognised Laboratories is available via <http://www.health.govt.nz/water> (under Drinking-water/Legislation/Related websites).

1.6.15 Records

The duty to keep records and make them available is covered in section 69ZD of the Act. Records must be kept of the results of monitoring drinking-water determinands. The records are necessary to demonstrate that the DWSNZ are being complied with. They are an essential requirement for the public health grading of drinking-water supplies. The records must include the following.

- The name of the supply, treatment plant(s) and distribution zone(s) to which the information relates and the unique supply component code listed in the Register of Drinking Water Suppliers for New Zealand (<http://www.health.govt.nz/>). If the water supply has not been registered, this should be undertaken with the Ministry of Health.
- The relevant supply codes must be included in all correspondence with the Ministry of Health or drinking-water assessor (DWA).
- Up-to-date records of the resident population in the district served by the supply.
- The information that is recorded must, to the satisfaction of the DWA, be sufficient for the purposes of assessing compliance with the DWSNZ.
- Online data records may be compressed using a procedure that preserves the accuracy of the original measurements. Data must be reported as a percentage of the time (or duration, where required) that the value was exceeded (or met) during the compliance monitoring period.
- Information collected during catchment assessments, sanitary inspections of the water supply, inspections of bore head protection, and data gathered during the protozoal risk categorisation process.
- All monitoring results of the raw water or water entering the treatment plant that are required for the protozoal risk categorisation.
- The treatment processes in operation at the beginning of the year being reported and any modifications that changed the process during the previous year.
- Unless analysing for Priority 2a determinands, the concentration of any impurities in the chemicals being dosed. This should include the calculations used that proved analysis of the impurities was not needed.
- Anything that could significantly affect water quality that has occurred in the drinking-water supply system or catchment.
- A log of observations made of the appearance of the source water where regular source inspections are required.
- The determinands monitored during the year. If any Priority 1 or Priority 2 determinands have not been monitored or have been monitored at less than the required frequency, the reasons must be recorded, with corroborating data where appropriate.
- The sampling frequency for each determinand, the dates and times on which the measurements were made (for samples before and after flushing where this is necessary), the sampling site location, the supply component code, the name of the sampler(s) and the analytical results.
- Any remedial action taken as a result of the level of a determinand exceeding the MAV or because the water supplier considered it necessary.

- The analytical method used and the limit of detection and uncertainty for each of test method.
- The name of the laboratory used for the analyses as listed in the Ministry of Health's Register of Recognised Laboratories for New Zealand
<http://www.health.govt.nz/water>.
- Any re-evaluation of the operational programme undertaken and the reasons for this. Notes concerning treatment modification have been discussed above, but changes in the operation or the materials used in the reticulation should also be noted where appropriate.
- Operational records, including process changes and operational monitoring.
- Copies of all equipment validations or certifications.
- The names, relevant qualifications and experiences of staff supervisors and operators.

Proper internal documentation of the monitoring programme will enable water suppliers to collate this information easily. Using the Drinking-water Online database (available through the Ministry of Health) will assist suppliers to calculate compliance and maintain the necessary records in the correct format.

1.7 Other drinking-water requirements

1.7.1 Drinking-water quality at airports

Annex 1 B 1(d) of the International Health Regulations (IHR) (WHO 2005) requires every designated airport location worldwide to develop the capacity to provide potable water for the aircraft that use their facilities. However, it is the responsibility of each aircraft operator to ensure that these standards are being upheld, not just in terms of the quality of the water taken on board from the source of supply on the ground. In accordance with Article 24(c) of the IHR (WHO 2005) states shall take all practicable measures to ensure that conveyance operators keep the water system free of sources of contamination and infection.

Airports should comply with the core capacity requirements of Annex 1 B 1(d) and the role of the competent authorities to ensure, as far as practicable, that the facilities are in sanitary condition and kept free of sources of infection and contamination, as per Article 22(b), such as providing potable water from a uncontaminated source approved by the competent authority.

For further information, see WHO (2009).

Note that the US established in 2009 an Aircraft Drinking Water Rule, for details, see <http://water.epa.gov/lawsregs/rulesregs/sdwa/airlinewater/index.cfm>

1.7.2 Drinking-water quality in shipping

Historically ships have played an important role in transmitting infectious diseases around the world. For example, the spread of cholera pandemics in the 19th century was thought to be linked to trade routes, and facilitated by merchant shipping.

The purpose of the International Health Regulations is “to provide security against the international spread of disease while avoiding unnecessary interference with international traffic”.

Waterborne outbreaks have been associated with loading poor quality water. Therefore, the first waterborne disease prevention strategy should be to load ships with the safest water available at port. To support this objective, ports should make good quality potable water available to ships.

Potable water for ships, including water-boats and water-barges, needs to be obtained only from those water sources and water supplies that provide potable water of a quality in line with the standards recommended in the *Guidelines for Drinking-water Quality* (WHO 2004), especially in relation to bacteriological requirements and chemical and physical requirements.

Potable water would typically need to be obtained from those watering points approved by the health administration or health authority. Facilities include piping, hydrants, hoses and any other equipment necessary for the delivery of water from shore sources at the pier or wharf area to the filling line for the ship’s potable water system. Plans for the construction or replacement of facilities for loading potable water aboard vessels would typically be submitted to the port health authority or other designated authority for review.

For further information, see WHO (2007 and 2011a).

Note: The International Health Regulations (2005), hereafter referred to as IHR (2005), are an international WHO legal framework addressing risks of international disease spread and legally binding on 194 states parties throughout the world, including all 193 WHO member states. The IHR (2005) are very broad, focusing upon almost all serious public health risks that might spread internationally, whether biological, chemical or radionuclear in origin, and whether transmissible in goods (including food), by persons, on conveyances (aircraft, ships, vehicles), through vectors or through the environment. The IHR (2005) contain rights and obligations for states parties (and functions for WHO) concerning prevention, surveillance and response; health measures applied by States to international travellers, aircraft, ships, ground vehicles and goods; and public health at international ports, airports and ground crossings. For more information, see <http://www.who.int/csr/ihr/en/>.

1.8 Emergency supplies and emergencies

Emergencies may result from contamination of the source water, loss of supply from the source due to drought or flood damage, failure at the treatment plant, or distribution system problems due to main breaks, pump failure, power supply failure, earthquake, etc.

Emergencies and contingencies are discussed in a general or planning manner in Chapter 2 of the Guidelines, sections 2.1, 2.2, 2.2.2.3, 2.2.2.4, 2.2.2.5, 2.2.3, and 2.2.4.2.

When the drinking-water may not be safe to drink, some water suppliers invoke a boil water notice (Chapter 6 includes an Appendix: Boil Water Notices). Other water suppliers may deliver water by tanker: see section 1.5.4 of these Guidelines and Ministry of Health (2008).

Some water suppliers have developed emergency water supplies specifically for longer term use after events such as earthquakes.

Emergency supplies must meet Priority 1 MAVs or requirements.

However, chemical determinands are less serious because their MAVs are based on consumption of two litres per day over a lifetime, ie, chronic MAVs. Aesthetic determinands are even less serious, unless the taste or odour is sufficient to cause consumers to seek an alternative, and possibly less safe, source.

During an emergency the concentration of a chemical determinand may exceed its MAV. Whether this is important will depend on the chemical, its concentration and duration. See section 10.2.3 and, particularly, section 10.2.5 of the Guidelines for discussion about acute MAVs and their derivation.

Chemical determinands can cause health or aesthetic issues due to volcanic eruptions, or accidental discharges or spills upstream of a water supply intake. Managers of water supplies at risk are advised to communicate with the various organisations in their area with responsibility for managing hazardous wastes. These include the Fire Service, NZ EPA, Police, regional councils and territorial local authorities. The National HazMat Coordination Committee (NHCC) is chaired by the NZFS, and comprises senior representatives from the NZ EPA, Worksafe New Zealand, New Zealand Police, the Ministry of Health, Maritime New Zealand, Civil Aviation Authority, New Zealand Defence Force, and Responsible Care New Zealand.

Bush fires are common in Australia and can have serious effects on water supplies. Their Department of Health has published guidance for people using rainwater supplies, Australian DoH (2011). Guidance on fire retardant chemicals has also been published, see Victoria State Government (2015) and Queensland Government (2018).

Appendix 1: Statistical issues that relate to the Drinking-water Standards of New Zealand

Contents

A1	Compliance rules for percentile standards	50
	Classical evaluation of risks	50
	Bayesian evaluation of risks	52
	Choice of priors	53
	Timeframe for compliance	53
	Compliance for small supplies	54
	Compliance for other supplies	54
A2	Handling non-detects	56

List of tables

Table A1.1:	Numbers of samples and allowable transgressions needed to keep maximum risks below 5 percent when assessing compliance with a 95th percentile standard	51
Table A1.2:	Allowable exceedances (for 95 percent confidence that the MAV is exceeded for no more than 5 percent of the time)	55

List of figures

Figure A1:	Bayesian confidence of compliance curves for a 95th percentile standard, using Jeffreys' uninformative	52
Figure A2:	Fitting a lognormal distribution to >L data (where L = 5), and extrapolating back to obtain values of <L data	57

Two issues are presented in outline herein:

- developing compliance rules for percentile standards
- handling non-detect data.

The 1995 Guidelines had a rather full presentation of these, but recent publications: Helsel 2005 and McBride 2005, have elucidated the arguments in full and need not be repeated.

A1 Compliance rules for percentile standards

The purpose of a drinking-water monitoring programme is to get as accurate a picture of the water quality as possible over the period of time and geographical area of interest. The reliability of the picture produced by the monitoring data is dependent on, amongst other things, the number of samples taken to construct it. The larger the number of samples, the more reliable the conclusions reached about the water quality are likely to be. Samples should be taken at random. Systematic sampling can introduce bias into the results by failing to detect patterns occurring outside the sampling schedule. Constraints on the resources available for monitoring programmes, however, limit the number of samples that can be collected. It is therefore necessary to use statistical calculations to determine the number of samples that must be taken to provide the required level of confidence in the conclusions reached from the data.

The *Drinking-water Standards for New Zealand (2005, revised 2008, and revised 2018)* (DWSNZ) are designed to work to 95 percentile standards (as discussed in section 6.2 of these Guidelines). Hereafter we will discuss only the 95th percentile case.

In other words, they aim to ensure that in a supply that complies with the DWSNZ, health-significant determinands are present at levels less than their MAVs for 95 percent or more of the time. Note that this is 95 percent of the time, not 95 percent of the samples. This is a deliberate choice. Variability in such things as the quality of the water and false positive results mean that with the limited monitoring data available, there will be a degree of uncertainty as to the ability of a supply to meet the 95th percentile requirement. The DWSNZ are based on a 95 percent confidence that the 95th percentile is being met. From these two parameters, 95 percent confidence in acceptable water quality for 95 percent of the time, the number of monitoring samples required for demonstrating compliance can be calculated.

In the 1995 edition of the DWSNZ these calculations were made using classical statistical methods. In the DWSNZ 2000 and 2005/2008 the classical basis has been replaced by the use of a Bayesian statistical method. The main consequence of this change is that fewer samples need to be taken to demonstrate the same level of confidence in compliance than was the case when the classical calculations were used.

Classical evaluation of risks

When evaluating whether the value of a determinand is less than, or equal to, its MAV for 95 percent of the time in a classical framework, one of two types of error can be committed:

- 1 from the number of transgressions it is incorrectly inferred that there was non-compliance. The risk of this occurring is termed the 'supplier's risk'
- 2 from the number of transgressions it is incorrectly inferred that there was compliance. The risk of this occurring is termed the 'consumer's risk'.

To quantify these risks using classical statistical methods it is assumed that sampling is random in time. To perform these calculations the probability of a single sample transgressing its MAV must be selected. This is done by assuming that the water is borderline for compliance, ie, the probability of the sample exceeding its MAV is 5 percent (95 percent of the time the MAV is not exceeded implies that 5 percent of the time it is, if the situation is borderline). This assumption of course makes for a very pessimistic approach.

The results obtained from the classical calculations are shown in Table A1.1. They are the basis for the statements made in section 1.3 of the DWSNZ 1995, showing how the number of samples necessary to demonstrate compliance 95 percent of the time depends on the number of samples exceeding the MAV. To keep the consumer's risk to less than 5 percent therefore requires a minimum of 59 samples to be taken, none of which are permitted to transgress the MAV. If one of the monitoring samples transgresses its MAV, there must be at least another 92 that have not exceeded the MAV to be 95 percent confident that the supply is in compliance 95 percent of the time.

Table A1.1: Numbers of samples and allowable transgressions needed to keep maximum risks below 5 percent when assessing compliance with a 95th percentile standard

Number of allowable transgressions	Number of samples required to keep the maximum consumer's risk below 5% using the following methods		Number of samples required to keep the maximum supplier's risk below 5% using the following methods	
	Classical	Bayesian*	Classical	Bayesian*
0	59–92 [#]	38–76 [#]	1 ⁺	[‡]
1	93–123	77–108	2–7	1–3
2	124–152	109–138	8–16	4–11
3	153–180	139–166	17–28	12–22
4	181–207	167–193	29–40	23–34
5	208–233	194–220	41–53	35–46
6	234–259	221–246	54–67	47–60
7	260–285	247–272	68–81	61–74
8	286–310	273–298	82–95	75–88
9	311–335	299–323	96–110	89–102

* These Bayesian results are obtained using Jeffreys' uninformative prior, as discussed in the next section.

It is not possible to keep the consumer's risk below 5 percent if less than 59 samples are to hand (classical method) or if less than 38 samples are to hand (Bayesian method with an uninformative (Jeffreys') prior).

+ The risk is exactly 5 percent in this case.

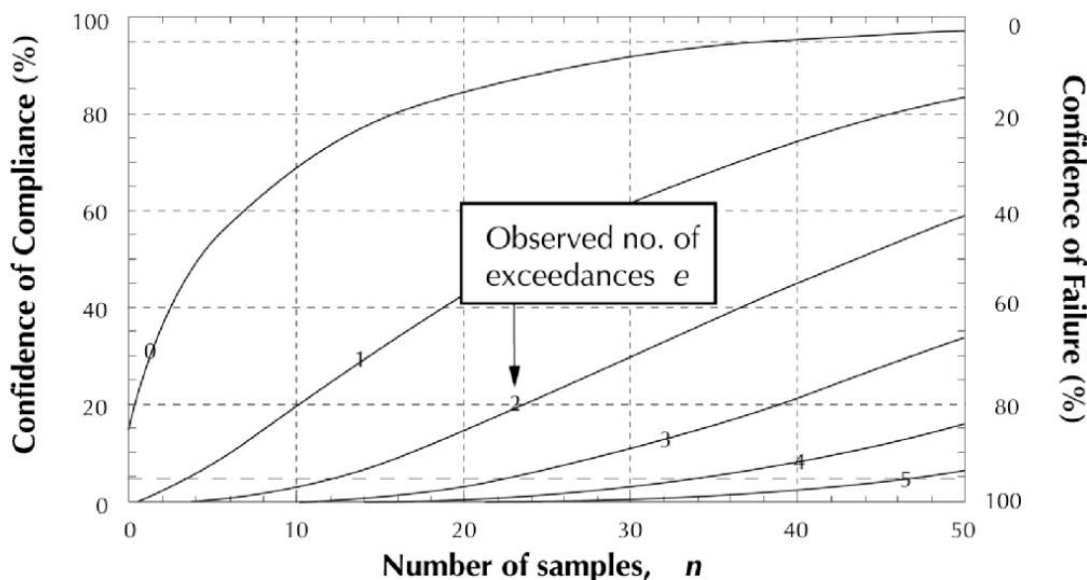
‡ It is impossible to keep the supplier's risk below 5 percent if no transgressions are allowed in this Bayesian approach.

Bayesian evaluation of risks

In the classical approach to calculating these calculations no use is made of any previously obtained data or opinions; a single particular value of the probability of an exceedance occurring is selected (5 percent in this case). In using the Bayesian approach, the probability of exceedance is regarded as a continuous variable about which confidence statements can be made. To do this, use is made of prior knowledge, or opinion, to define beforehand a 'prior' probability distribution. This probability can then be upgraded using the actual data collected to obtain a 'posterior' probability that is termed the 'Confidence of Compliance'. Note that this approach does not require the borderline assumption, so results are *always* less pessimistic than those obtained under the classical approach, for every possible prior.

These calculations lead to Figure A1 from which the required number of samples for a given number of allowable transgressions can be read. Key values from the data sets used to produce these plots are summarised in Table A1.1. These values were contained in Table A1.4 of the 2005 DWSNZ (revised 2008, revised 2018). They now appear as Table A1.2 in this chapter of the Guidelines.

Figure A1: Bayesian confidence of compliance curves for a 95th percentile standard, using Jeffreys' uninformative



The desired maximum supplier's risk (5 percent) corresponds to confidence of failure = 95 percent, as shown by the long dashed line on each graph. The desired maximum consumer's risk (5 percent) corresponds to confidence of compliance = 95 percent, as shown by the short dashed line on each graph. Details of the calculation procedure and the details of Jeffreys' prior, are given in McBride and Ellis (2001) and McBride (2005).

Choice of priors

Using the Bayesian approach requires a decision to be made about the nature of the prior probability distribution (the 'prior'). When there is no historical information on which to base a prior, the common-sense approach is to adopt an 'uninformative' prior that best reflects our ignorance of the likelihood of compliance. The calculations for Figure A1, from which results for the DWSNZ were obtained, use the Jeffrey's (uninformative) prior. Strictly, there is no such thing as a truly 'uninformative' prior; any statement about the probability of the state of things is saying something. Nevertheless, the term 'uninformative' is in widespread use in the Bayesian statistical literature. Arguments in favour of the (U-shaped) Jeffrey's prior are given in McBride and Ellis (2001).

There may be situations, however, in which there is prior knowledge of the likelihood of compliance. Bayesian Confidence of Compliance calculations allow account to be taken of this knowledge, and the numbers of samples needing to be taken appropriately modified.

Timeframe for compliance

The statistics provided in Table A1.1 are independent of time. The number of transgressions that can occur while still keeping the risk to the consumer to less than 5 percent and hence comply with the DWSNZ depends only upon the number of samples taken. For example, if two transgressions are recorded, so long as at least 107 other samples (giving a total of 109) have not exceeded the MAV, the risk to the consumer is less than 5 percent irrespective of the period over which the samples were collected.

For the purposes of compliance, however, it is necessary to set a time period within which the statistics are to be applied. The reason for this is demonstrated by considering a situation in which 48 samples are collected per year for three years (total 144 samples), and that only two of these samples exceed the MAV, both in the last two months of sampling. When the whole three years is considered, the risk to the consumer is less than 5 percent because a maximum of three transgressions is allowed for 144 samples (see the first Bayesian column in Table A1.1). However, the fact that both transgressions occur in a short period indicates that there may well be a water quality problem that has developed near the end of the three-year period. This possible problem is correctly identified if a shorter period for assessing compliance is defined: for example, one year. Now, for the first two years in which there were no transgressions, the number of samples taken meets the requirements of Table A1.1 (a minimum of 38 samples taken if there is no exceedance). The supply does not comply in the last year however, because there are two transgressions during this year, and Table A1.1 requires a minimum of 109 samples to have been taken to reduce the consumer's risk to less than 5 percent.

For the purposes of the DWSNZ, the period over which compliance is assessed has been indexed to the community size, as has the sampling frequency, which should assist in minimising these issues.

Compliance for small supplies

Small supplies have been given the benefit of the doubt to allow a reduction in the burden that collection of 38 samples a year would otherwise place on them. In doing this it is assumed that 12 non-transgressions indicates no transgressions at least 95 percent of the time. However, in the event that one sample exceeds the MAV, there is evidence that the 95th percentile standard may not be being met, and further sampling requirements set out in the DWSNZ must be followed.

Compliance for other supplies

Table A1.2 lists the number of exceedances that can be tolerated for 95 percent confidence that a benchmark is not being exceeded more than 5 percent of the time.

The table refers to the number of samples, irrespective of the frequency of sampling. Thus, the number of permissible transgressions in 250 samples is the same (seven) whether all 250 samples were collected in one day or taken over the course of a year.

Table A1.2: Allowable exceedances (for 95 percent confidence that the MAV is exceeded for no more than 5 percent of the time)

<i>e</i>	<i>n</i>	<i>e</i>	<i>n</i>	<i>e</i>	<i>n</i>	<i>e</i>	<i>n</i>
0	38–76	40	1025–1046	80	1908–1929	120	2773–2793
1	77–108	41	1047–1069	81	1930–1951	121	2794–2815
2	109–138	42	1070–1091	82	1952–1973	122	2816–2836
3	139–166	43	1092–1113	83	1974–1994	123	2837–2858
4	167–193	44	1114–1136	84	1995–2016	124	2859–2879
5	194–220	45	1137–1158	85	2017–2038	125	2880–2900
6	221–246	46	1159–1181	86	2039–2060	126	2901–2922
7	247–272	47	1182–1203	87	2061–2081	127	2923–2943
8	273–298	48	1204–1225	88	2082–2103	128	2944–2965
9	299–323	49	1226–1247	89	2104–2125	129	2966–2986
10	324–348	50	1248–1270	90	2126–2146	130	2987–3007
11	349–372	51	1271–1292	91	2147–2168	131	3008–3029
12	373–397	52	1293–1314	92	2169–2190	132	3030–3050
13	398–421	53	1315–1336	93	2191–2211	133	3051–3072
14	422–445	54	1337–1358	94	2212–2233	134	3073–3093
15	446–469	55	1359–1381	95	2234–2255	135	3094–3114
16	470–493	56	1382–1403	96	2256–2276	136	3115–3136
17	494–517	57	1404–1425	97	2277–2298	137	3137–3157
18	518–541	58	1426–1447	98	2299–2320	138	3158–3178
19	542–564	59	1448–1469	99	2321–2341	139	3179–3200
20	565–588	60	1470–1491	100	2342–2363	140	3201–3221
21	589–611	61	1492–1513	101	2364–2384	141	3222–3243
22	612–635	62	1514–1535	102	2385–2406	142	3244–3264
23	636–658	63	1536–1557	103	2407–2427	143	3265–3285
24	659–681	64	1558–1579	104	2428–2449	144	3286–3307
25	682–704	65	1580–1601	105	2450–2471	145	3308–3328
26	705–727	66	1602–1623	106	2472–2492	146	3329–3349
27	728–751	67	1624–1645	107	2493–2514	147	3350–3371
28	752–774	68	1646–1667	108	2515–2535	148	3372–3392
29	775–796	69	1668–1689	109	2536–2557	149	3393–3413
30	797–819	70	1690–1711	110	2558–2578	150	3414–3434
31	820–842	71	1712–1733	111	2579–2600	151	3435–3456
32	843–865	72	1734–1755	112	2601–2621	152	3457–3477
33	866–888	73	1756–1776	113	2622–2643	153	3478–3498
34	889–910	74	1777–1798	114	2644–2664	154	3499–3520
35	911–933	75	1799–1820	115	2665–2686	155	3521–3541
36	934–956	76	1821–1842	116	2687–2707	156	3542–3562
37	957–978	77	1843–1864	117	2708–2729	157	3563–3583
38	979–1001	78	1865–1886	118	2730–2750	158	3584–3605
39	1002–1024	79	1887–1907	119	2751–2772	159	3606–3626

Note: 'e' is the maximum permissible number of exceedances of a 95 percentile limit for the stated range of samples 'n'. Calculations have been made using the theory stated in McBride and Ellis (2001), using 'Jeffreys' prior'. (See also McBride 2005, section 8.4.)

A2 Handling non-detects

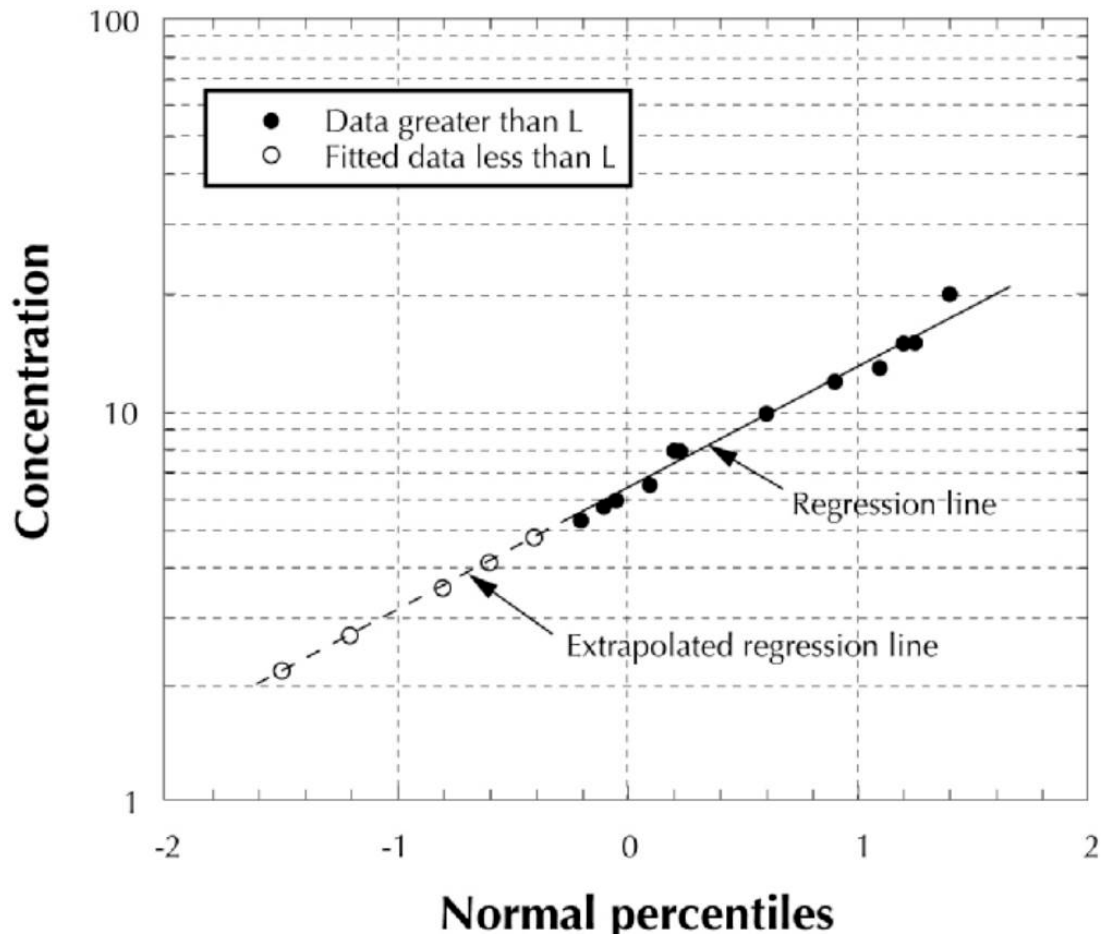
New Zealand chemical analysts routinely define a detection limit or limit of detection as some multiple (typically between 2 and 4) of the standard deviation of a series of blanks, and report all data measured below that limit as less than that limit. Let's denote the detection limit by L . Three cases should be considered.

- 1 **Few less-than data.** When a dataset contains only a few data (say <10 percent) below L , analysis of those data can proceed by replacing those (left-censored) data by $\frac{1}{2}L$. This is a generally satisfactory procedure (Ellis 1989).
- 2 **A moderate amount of less-than data.** If there are a moderate number of censored data, replacement by $\frac{1}{2}L$ is unsatisfactory. Instead, use a statistical distribution fitting method (Helsel and Hirsch 1992, and Helsel 2005), as depicted on Figure A1, ie:
 - fit a plausible statistical distribution to the data above L (eg, using a probability plot)
 - extrapolate that distribution below L to fill-in values below L
 - add up the concentrations.
- 3 **Mostly, or all, less-than data.** If there are many less-thans in a dataset neither of the above procedures can be used. For example, take a set of results for ten individual chemicals: <0.1, <0.1, <0.1, <0.1, <0.1, <0.1, <0.1, <0.1, 0.8, <0.1. What then is the total? Replacing each '<0.1' by 0.1 is implausible (could all nine less-thans really be 'knocking at the door?'), and we should not fit a distribution to just one datum.¹² Even replacement by 0.05 seems implausible.

Taking data at face-value we could say that the range of total concentration is 0.8–1.7, where the former figure is obtained by replacing all the censored data by zeroes and the latter figure by replacing those data by the detection limits. Beyond that little statistical help is available, and one must rely on plausibility arguments. One should also note that it is much better practice to analyse the compounds with a method that has a lower limit of detection, reducing the number of measurements if budgets are limited.

¹² Actually, we can: *any* distribution fits just one datum!

Figure A2: Fitting a lognormal distribution to >L data (where L = 5), and extrapolating back to obtain values of <L data



Each fill-in value (open circles) is selected randomly from the left tail of a lognormal distribution.

References

- Australian DoH. 2011. *Guidance on Use of Rainwater Tanks: Preventing Impacts on Aesthetic Quality*. Department of Health.
<http://www.health.gov.au/internet/publications/publishing.nsf/Content/ohp-enhealth-raintank-cnt-l~ohp-enhealth-raintank-cnt-l-5~ohp-enhealth-raintank-cnt-l-5.7>
- Ball A. 2007. *Estimation of the Burden of Waterborne Disease in New Zealand: Preliminary report*. Christchurch: ESR.
- Baker M, Russell N, Roseveare C, et al. 1998. Outbreak of cryptosporidiosis linked to Hutt Valley swimming pool. *The New Zealand Public Health Report* 5(6): 41–5.
- Bartram J. 2003. Investigation of sporadic waterborne disease. Preface to section 3 (on Investigation of Sporadic Waterborne Disease) in PR Hunter, M Waite, E Ronchi. 2003. *Drinking Water and Infectious Disease*. Boca Raton, LA: CRC Press and IWA Publishing.
- Beca. 2001. *Drinking Water Compliance Assessment*. A report prepared (in March) for the Ministry of Health by Beca Steven in association with BERL.
- Brieseman MA. 1987. Town water supply as the cause of an outbreak of *Campylobacter* infection. *New Zealand Medical Journal* 100: 212–13.
- CH2M Beca. 2010. *Drinking Water Standards New Zealand Cost Benefit Analysis – Engineering Input*. 103 pp. <http://www.health.govt.nz/publication/drinking-water-cost-benefit-analysis>
- Craun G, Till DG, McBride GB. 2004. Epidemiological studies and surveillance. Chapter 10 in: JA Cotruvo, A Dufour, G Rees, et al. *Waterborne Zoonoses: Identification, Causes and Control*. London: IWA Publishing, for the World Health Organization. Available at: http://www.who.int/water_sanitation_health/diseases/zoonoses/en/
- Duncanson M, Russell N, Weinstein P, et al. 2000. Rates of notified cryptosporidiosis and quality of drinking water supplies in Aotearoa, New Zealand. *Water Research* 14(15): 3804–12.
- Dupont DP, Jahan N. 2012. Defensive spending on tap water substitutes: the value of reducing perceived health risks. *J Water and Health* 10(1): 56–68.
- Eberhardt-Phillips J, Walker N, Garrett N, et al. 1997. Campylobacteriosis in New Zealand: results of a case-control study. *Journal of Epidemiology and Community Health* 51: 686–91.
- Ellis JC. 1989. *Handbook on the Design and Interpretation of Monitoring Programmes*. Water Research Centre Report NS29. England: Medmenham.
- ESR. *Annual Summary of Outbreaks in New Zealand*. Wellington: ESR. See www.surv.esr.cri.nz then select surveillance reports, annual surveillance summary for the year desired, and then selected tables.
- Fraser G, Cooke KR. 1991. Endemic giardiasis and municipal water supply. *American Journal of Public Health* 81(6): 760–2.

- Frost F, Calderon RL, Craun GF. 2003. Improving waterborne disease surveillance. Chapter 2 in FW Pontius (ed) *Drinking Water Regulation and Health*. New York, NY: Wiley-Interscience.
- Harrington W, Krupnick A, Spofford W. 1985. The benefits of preventing an outbreak of giardiasis due to drinking water contamination. *Resources for the Future Report*. Washington: US Environmental Protection Agency, National Center for Environmental Economics.
- Helsel DR, Hirsch RM. 1992. *Statistical Methods in Water Resources*. *Studies in Environmental Science* 49. Amsterdam: Elsevier. Chapter 13.
- Helsel DR. 2005. *Nondetects and Data Analysis: Statistics for censored environmental data*. New York: Wiley.
- Hrudey SE, Hrudey E. 2004. *Safe Drinking Water: Lessons from Recent Outbreaks in Affluent Nations*. London: IWA Publishing.
- Hrudey SE. 2017. *Converting Hindsight into Foresight. Evidence prepared for Water New Zealand for submission to Government Inquiry into North Havelock Drinking-Water*. 60 pp. [https://www.dia.govt.nz/diawebsite.nsf/Files/Havelock-North-Submissions/\\$file/Havelock-Submissions-Hrudey-Mar-31.pdf](https://www.dia.govt.nz/diawebsite.nsf/Files/Havelock-North-Submissions/$file/Havelock-Submissions-Hrudey-Mar-31.pdf)
- Hunter P, Waite M, Ronchi E. 2003. *Drinking Water and Infectious Disease: Establishing the Links*. London: CRC Press Boca Raton and IWA Publishing.
- Hutton G, Haller L. 2004. *Evaluation of the Costs and Benefits of Water and Sanitation Improvements at the Global Level*. WHO/SDE/WSH/04.04. Geneva: WHO. See: http://www.who.int/water_sanitation_health/wsh0404/en/
- IANZ. 2000. *General Requirements for the Competence of Testing and Calibration Laboratories* (NZS/ISO/IEC 17025).
- IANZ. 2007. *Supplementary Criteria for Accreditation No. 1.2/2.2* (2nd edition). Auckland: Ministry of Health Register of Water Testing Laboratories, International Accreditation New Zealand. See: <http://www.ianz.govt.nz>
- Ionas G, Learmonth JJ, Keys EA, et al. 1999. Distribution of *Giardia* and *Cryptosporidium* in natural water systems in New Zealand – a nationwide survey. *Water Science and Technology* 38(12): 57–60.
- Lake R, Adlam B, Perera S. 2009. *Acute Gastrointestinal Illness (AGI) Study: Final study report*. Christchurch: ESR.
- LECG. 2010. *Cost Benefit Analysis of Raising the Quality of New Zealand Networked Drinking Water*. Report to the Ministry of Health. 274 pp. <http://www.health.govt.nz/publication/drinking-water-cost-benefit-analysis>
- McBride GB, Ellis JC. 2001. Confidence of compliance: a Bayesian approach for percentile standards. *Water Research* 35(5): 1117–24.
- McBride GB. 2005. *Using Statistical Methods for Water Quality Management: Issues, Options and solutions*. New York: Wiley.

- McBride G, Till D, Ryan T, et al. 2002. *Freshwater Microbiology Research Report: Pathogen occurrence and human health risk assessment analysis*. Wellington: Ministry for the Environment.
- McElnay C, Inkson I. 2002. Outbreak of *Campylobacter* in Hawke's Bay traced to school water supply. In: *Annual Summary of Outbreaks in New Zealand 2001: A report to the Ministry of Health*. Wellington: Institute of Environmental Science and Research Limited (ESR).
- Ministry of Health. 1992 to present day. *Annual Reviews of Drinking-water Quality in New Zealand*. Wellington: Ministry of Health.
- Ministry of Health. 1993 to present day. *Register of Community Drinking-water Supplies and Suppliers in New Zealand*. Wellington: Ministry of Health.
- Ministry of Health. 1995, 2000, 2005, 2008 and 2018. *Drinking-water Standards for New Zealand*. Wellington: Ministry of Health.
- Ministry of Health. 2001. *How to Prepare and Develop Public Health Risk Management Plans for Drinking-water Supplies*. Wellington: Ministry of Health.
- Ministry of Health. 2008. *Guidelines for the Safe Carriage and Delivery of Drinking-water*. <https://www.health.govt.nz/publication/guidelines-safe-carriage-and-delivery-drinking-water>
- Ministry of Health. 2015. *Rural Agricultural Drinking-water Supply Guideline*. Wellington: Ministry of Health. 12 pp. <http://www.health.govt.nz/publication/rural-agricultural-drinking-water-supply-guideline>
- Ministry of Health. 2018. New Zealand Drinking-water Safety Plan Framework. <https://www.health.govt.nz/publication/new-zealand-drinking-water-safety-plan-framework>
- Nokes C, Devane M, Scholes P, et al. 2004. Survey of *Campylobacter* in New Zealand's treated drinking waters. *Proceedings of the New Zealand Water and Wastes Annual Conference and Expo*. Christchurch, 6–8 October.
- OECD. 2011. *Benefits of Investing in Water and Sanitation: An OECD perspective*. OECD Publishing. 151 pp. <http://dx.doi.org/10.1787/9789264100817-en>
- Ogilvie DJ. 1989. Water supply questionnaire, disinfection and bacteriology. *New Zealand Water Supply and Disposal Association Newsletter* (now *New Zealand Water & Wastes Association Journal*). Part I, issue #55: 8–14; Part II, issue #56: 19–26; Part III, issue #57: 20–4.
- OMS. 2004. *Assistance Options for Safer Drinking Water Systems: Report to the Ministry of Health*. Wellington: Outcome Management Services Ltd.
- Payment P, Hunter P. 2003. Intervention studies. In PR Hunter, M Waite, E Ronchi. 2003. *Drinking Water and Infectious Disease*. Boca Raton, LA: CRC Press and IWA Publishing.
- Percival S, Chalmers R, Embrey M, et al. 2004. *Microbiology of Water-borne Diseases*. Amsterdam: Elsevier Academic Press.
- Pretty JN, Brett C, Gee D, et al. 2000. An assessment of the total external costs of UK agriculture. *Agricultural Systems* 65: 113–36.

- Queensland Government. 2018. Fire Retardants and Health. <https://www.qld.gov.au/health/staying-healthy/environmental/after-a-disaster/bushfires/fire-retardants-and-health>
- Reilly WJ, Browning LM. 2004. Zoonoses in Scotland – food, water, or contact? Chapter 11 in JA Cotruvo, A Dufour, G Rees, et al (eds.). *Waterborne Zoonoses Identification, Causes and Control*. London: IWA Publishing, for the World Health Organization, pp 167–190. Available at: http://www.who.int/water_sanitation_health/diseases/zoonoses/en/
- Reimann C, Banks D. 2004. Setting action levels for drinking water: are we protecting our health or our economy (or our backs!). *Science of the Total Environment* 332: 12–21.
- Sapere Research. 2013. *The 2012 Waterborne Disease Outbreak in a Small Town in New Zealand: An estimate of costs*. Report prepared by the Sapere Research Group for the Ministry of Health. 55 pp.
- Sapere Research. 2017. *The Economic Costs of the Havelock North August 2016 Waterborne Disease Outbreak*. Report prepared by the Sapere Research Group for the Ministry of Health. 68 pp. <https://www.health.govt.nz/publication/economic-costs-havelock-north-august-2016-waterborne-disease-outbreak>
- Savill MG, Hudson JA, Ball A, et al. 2001. Enumeration of *Campylobacter* in New Zealand recreational and drinking waters. *Journal of Applied Microbiology* 91: 38–46.
- Schuster CJ, Aramini JJ, Ellis AG, et al. 2005. Infectious disease outbreaks related to drinking water in Canada 1974–2001. *Revue Canadienne de Santé Publique* 96(4): 254–8.
- Shaw CP. 1993. *The New Zealand Drinking-water Standards – a preview*. New Zealand Water and Wastes Association Annual Conference, September.
- Simmons G, Hope V, Lewis G, et al. 2001. Contamination of potable roof-collected rainwater in Auckland, New Zealand. *Water Research* 35(6): 1518–24.
- Sneyd E, Baker M. 2003. *Infectious Diseases in New Zealand: 2002 annual surveillance summary*. ESR Client Report FW 0332, for New Zealand Ministry of Health.
- Stehr-Green JK, Nicholls C, McEwan S, et al. 1991. Waterborne outbreak of *Campylobacter jejuni* in Christchurch: the importance of a combined epidemiologic and microbiologic investigation. *New Zealand Medical Journal* 104: 356–8.
- Thorstensen AL. 1985. *What happened at Queenstown – an object lesson for water supply authorities*. New Zealand Local Government, February, p 455.
- Till DG, McBride GB. 2004. Potential public health risk of *Campylobacter* and other zoonotic waterborne infections in New Zealand. Chapter 12 in: JA Cotruvo, A Dufour, G Rees, et al. *Waterborne Zoonoses: Identification, Causes and Control*. London: IWA Publishing, for the World Health Organization. Available at: http://www.who.int/water_sanitation_health/diseases/zoonoses/en/
- Taylor MEU. 1993a. *Review of the Management of Drinking-water Quality in New Zealand*. New Zealand Water and Wastes Association Annual Conference, September.

Taylor MEU. 1993b. *Drinking-water for the 21st Century*. The second annual AIC Water Resources Industry Conference, Auckland, July.

Taylor MEU. 2000. Drinking-water management in New Zealand. *Water (J Australian Water and Waste Association)*, November issue.

Taylor M, Ball A. 2004. Why do we need safe water? Unpublished paper presented to the New Zealand Environment Summit, Wellington, 22 March 2004.

USEPA. 2003. *Small Drinking Water Systems Handbook: A guide to 'packaged' filtration and disinfection technologies with remote monitoring and control tools*. EPA/600/R-03/041. Office of Research and Development. Water Supply and Water Resources Division, United States Environmental Protection Agency. 73 pp.

<http://www.epa.gov/nrmrl/pubs/600r03041/600r03041.htm> now go to:
<http://nepis.epa.gov/Exe/ZyNET.exe/100046K6.TXT?ZyActionD=ZyDocument&Client=EPA&Index=2000+Thru+2005&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5Czyfiles%5CIndex%20Data%5C00thru05%5CTxt%5C00000006%5C100046K6.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=p%7Cf&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x&ZyPURL>

Victoria State Govt. 2015. *Fire Retardants and Health*.

<https://www2.health.vic.gov.au/public-health/environmental-health/environmental-health-in-the-community/fire-retardants-and-health>

Wheeler JG, Sethi D, Cowden JM, et al. 1999. Study of infectious intestinal disease in England: rates in the community, presenting to general practice, and reported to national surveillance. *British Medical Journal* 318(7190): 1046–50.

WHO. 2004. *Guidelines for Drinking-water Quality* (3rd edition). Geneva: World Health Organization. Available at:

www.who.int/water_sanitation_health/dwq/gdwq3/en/print.html see also the addenda.

WHO. 2005. *International Health Regulations (IHR)*. Geneva: World Health Organization. 82 pp. <http://www.who.int/ihr/9789241596664/en/index.html>

WHO. 2007. *International Health Regulations, Guide to Ship Sanitation* (3rd edition) draft, Version 10. Geneva: World Health Organization. 178 pp. Final version due December 2010.

http://www.who.int/water_sanitation_health/gdwqrevision/rrships/en/index.html

WHO. 2009. *Guide to Hygiene and Sanitation in Aviation* (3rd edition). Geneva: World Health Organization. 71 pp. See for general links:

http://www.who.int/ihr/ports_airports/en/ and also:

http://www.who.int/water_sanitation_health/gdwqrevision/aviation/en/index.html
http://www.who.int/water_sanitation_health/hygiene/ships/guide_hygiene_sanitation_aviation_3_edition.pdf

WHO. 2011. *Guidelines for Drinking-water Quality* 2011 (4th edition). Geneva: World Health Organization. Available at:
http://www.who.int/water_sanitation_health/publications/2011/dwq_guidelines/en/index.html

WHO. 2011a. *Guide to Ship Sanitation* (3rd edition). Geneva: World Health Organization. 171 pp.
http://whqlibdoc.who.int/publications/2011/9789241546690_eng.pdf

WHO. 2017. *Guidelines for drinking-water quality: fourth edition incorporating the first Addendum*. Geneva: World Health Organization. 631 pp.
http://www.who.int/water_sanitation_health/publications/drinking-water-quality-guidelines-4-including-1st-addendum/en/

WRC. 1998. *Wholesale Water Supply Risk Analysis Discussion Paper*. Wellington Regional Council.