FAILING THE DRINKING-WATER STANDARDS – INSIGHTS FROM THE ANNUAL SURVEY

Barry Mattingley, David Wood and Chris Nokes, ESR

ABSTRACT

Each year ESR surveys all networked water suppliers that provide water to more than 100 people for information on their achievement of the *Drinking-water Standards for New Zealand* (the Standards). This information is used to prepare the *Annual Report on Drinking-water Quality* for the Ministry of Health. The study reported here analysed four years of survey data 2010-2014 (341 zones). The study focused on zones that did not achieve the Standards for *E. coli* or chemicals. Its aim was to better understand the reasons for non-achievement to help improve risk management.

The study found the main reason for zones failing to meet the *E. coli* and chemical requirements of the Standards was too many transgressions (maximum acceptable value exceedences). Almost all zones with an excessive number of transgressions, for both *E. coli* and chemicals, served populations in the 501-5000 bracket. Corrective actions were considered adequate in 91% of zones with *E. coli* transgressions, despite repeated failures over the four years. In contrast, in 23% of zones with chemical transgressions, corrective actions were considered adequate.

Actions are being taken to address both bacteriological and chemical non-achievement in some zones. This should results in improve levels of achievement when treatment upgrades take effect.

KEYWORDS

Drinking-water Standards, non-achievement, transgressions, corrective actions, compliance

1 INTRODUCTION

The *Annual Report on Drinking-water Quality in New Zealand* (the Annual Report) has been published by the Ministry of Health (the Ministry) since 1994[1]. Before 2008, publication of the Annual Report was one of the tools used by the Ministry to encourage water suppliers to meet the voluntary *Drinking-water Standards for New Zealand* (the Standards). In 2008, the Health Act 1956 (the Act) (s69) made it a legal requirement for water suppliers "to take all practicable steps" to comply with the Standards[2], and also placed a legal responsibility on the Director-General of Health to publish the Annual Report (s69ZZZB).

The data on which the Annual Report is based are collected by the Annual Survey (the Survey) of water supplies. The Survey collects data from all networked water supplies in New Zealand that serve more than 100 people. In the July 2013–June 2014 year, this provided information on the quality of water received by approximately 3,829,000 people in 659 water supply zones.

As well as fulfilling the 69ZZZB requirement, the purpose of the Annual Report is to present a readily understood summary of the extent to which the water supplies meet the requirements of the Standards and comply with the Act. This provides a national overview of the quality of the country's drinking-water. The summaries in the Annual Report are based on an extensive dataset, only a fraction of which is evident from the information in the report. The study reported here is the first in a proposed series of studies looking in more detail at the full dataset that has been collected by the Survey.

[1] The most recent edition at the time of undertaking this study is available at http://www.health.govt.nz/publication/annual-report-drinking-water-quality-2013-14

[2] These requirements were phased in over a period of time depending on the size of the supply (see s 69C of the Act).

1.1 STUDY'S PURPOSE

The purpose of the study was to gain a better understanding of the reasons for non-achievement of the *E. coli* (*Escherichia coli*) and chemical requirements of the Standards in minor, medium and large water supplies. This understanding should lead to better public health risk management of the country's water supplies and improved national levels of achievement of the Standards. One of the reasons for the omission of protozoa achievement this first examination of the Survey data, was that protozoal non-achievement of the Standards is primarily due to the need for infrastructural upgrades. Hence, the reason for non-achievement is more clear cut for protozoa than for *E. coli* and chemical determinands.

There are two possible reasons for non-achievement of the Standards: too many transgressions[3] and inadequate monitoring. Transgressions provide direct evidence that the water quality was unsatisfactory at the time the sample was taken. For this reason, the study's primary interest was in failure to achieve the Standards because of transgressions.

2 METHOD

2.1 METHOD OF DATA GATHERING AND EVALUATION

2.1.1 THE ANNUAL SURVEY

The Survey is performed in Water Information New Zealand (WINZ) 6, a web database managed by ESR for the Ministry of Health. Each survey covers the distribution zones and treatment plants for all networked supplies where the zone population is over 100 people. Surveys start on 1 July each year, and cover the preceding 12 months of 1 July to 30 June.

The Survey covers both achievement of the Standards and compliance with the drinking-water aspects of the Act. Only those parts of the survey concerned with achievement of the Standards were of interest here.

Each Survey form, whether for a zone or a plant, has 3 sections.

a. Monitoring section: This is completed by either the supplier or the public health unit of the DHB. It includes questions on monitoring status, transgressions, etc, but does not specify achievement.

b. Audit section: This is completed by the public health unit and signed off by a drinking-water assessor. It states specifically whether the Standards were achieved, and whether leniency[4] was granted. Comments can be included to explain any decisions taken.

c. National section: ESR completes this section to confirm the entries are complete and consistent with national norms.

Each section cannot be completed until the one before it has been finalised. Similarly, earlier sections cannot be edited unless the current section is 'un-finalised' first. This helps to ensure a consistent process and audit trail of entries.

2.1.2 SURVEY ANALYSIS AND RISK ASSESSMENT DATA PREPARATION

The Survey data were extracted from WINZ 6, further checked and then processed in a separate database application called Surveyor. One output from Surveyor was a table of zone-based survey results that form the basis for the Annual Report.

The Surveyor database was able to calculate achievement for any survey year in WINZ 6 that had been answered with similarly formatted questions. At the time of the study there were four years of fully comparable data in WINZ 6, ie, 2010-11, 2011-12, 2012-13 and 2013-14.

[3] A transgression is the detection of *E. coli* in 100 ml of water, or a chemical determinand exceeding its MAV.
[4] 'Leniency' can be granted by a drinking-water assessor where there are extenuating circumstances for a sampling result not being obtained.

Data were further filtered for this study by requiring that each included zone must have data for all of the four years. Exclusions from the dataset included:

- supplies that were new after 2010–11;
- zones that were substantially restructured after 2010–11;
- some Christchurch and surrounding supplies that were not surveyed in 2010–11 because of the Canterbury earthquakes.

2.1.3 INFORMATION FROM DRINKING-WATER ASSESSORS

Seven drinking-water assessors had zones that failed the *E. coli* standard because of too many transgressions in the four years studied. These drinking-water assessors were asked for any more details they could provide about: concentrations of *E. coli* found in transgressing samples, reasons for transgressions, the corrective actions taken, and general comments about the zone or water supply and the way it was operated.

2.1.4 THE REPORT'S PRIMARY DATASETS AND SUBSETS

Table 1 sets out the criteria used to select the Survey data that were examined by the study. The available resources did not allow the Survey's full dataset to be examined. The selection criteria were designed to focus the study on zones with the greatest number of failures resulting from transgressions.

Table 1 Summary of criteria defining the primary dataset and subsets examined in more detail by the study

	Inclusion criteria	
	Primary dataset	**Subsets examined in more detail**
E. coli		
Annual Survey years	2010-11, 2011-12, 2012-13, 2013-14	As for the Primary dataset
Zone size	Greater than 500 (larger than 'Small', as defined by the Act)	
Failure to achieve the Standards	2013-14	
Excessive number of transgressions		Any of the four years
Chemical determinands		
Annual Survey years	2010-11, 2011-12, 2012-13, 2013-14	As for the Primary dataset
Zone size	Greater than 100	
Failure to achieve the Standards	2013-14	
Excessive number of transgressions		2013-14 and at least two of the three preceding years

The population criterion for *E. coli* non-achievement was not applied to the chemical determinand datasets, because Priority 2 determinands are generally only assigned to zones serving more than 500 people. Relaxing the population criterion to the lowest population included in the Survey, increased the number of zones for detailed study by only two. These were included to provide as complete a picture of chemical non-achievement as possible.

The methodology for compiling the primary datasets was designed to capture zones that met the criteria of Table 1. Zones that had undergone more than one zone code (the key to zone identification) change during the four year period of interest had to be omitted because of the difficulty in maintaining links between the changing

codes. One zone was not included in the primary chemical dataset for this reason. Some zones do not appear in the *E. coli* primary dataset for the same reason, however, they also failed to meet other criteria for inclusion in the report.

3 *E. COLI* NON-ACHIEVEMENT

3.1 FINDINGS AND DISCUSSION

3.1.1 OVERVIEW OF NON-ACHIEVEMENT FOR *E. COLI*

The number of zones supplying more than 500 people in 2013-14 was 360. The subset of zones with data available from 2010 to 2014 was 341 of which 37 zones failed to meet the *E. coli* requirements of the Standards in the 2013-14 year. Twenty six (70%) of the 37 zones failed, in at least one year of the four, because of too many transgressions. For brevity, this group of zones is referred to as the 'transgressing group'. Minor supplies, supplying a population of 501–5000 (inclusive), constitute the great majority (24/26 or 92%) of the 'transgressing group'.

For the purposes of later discussion the 'transgressing group' is split into two subgroups. The first subgroup, referred to as the 'high transgression zones', contains 10 zones that failed because of too many transgressions in 2013-14 and in at least two of the three preceding years. The second subgroup (16 zones), referred to as the 'moderate transgression zones', contains the remainder of the 'transgressing group' and defines a second tier of non-achievement.

An excessive number of transgressions was the primary reason for 79% (57/72) of the annual failures[5] to meet the *E. coli* standards by the 'transgressing group'. Inadequate monitoring alone was the reason for non-achievement of the Standards in only 21% (15/72) of cases. When the *E. coli* standards were not achieved because of transgressions, corrective actions to address the transgressions were considered adequate in 91% (52/57) of failures.

3.1.2 NON-ACHIEVEMENT BECAUSE OF TRANSGRESSIONS

Within the 'transgressing group', the 'high transgression zones' are of primary interest because they show the worst levels of *E. coli* transgression for zones in the primary dataset. Four of these 10 zones failed in all four years, and the remainder in three of the four years, because of too many transgressions. Clearly, these suppliers experienced difficulties in avoiding transgressions. Understanding the causes of these transgressions and what could be done to stop their recurrence should be helpful in identifying actions to improve levels of achievement.

Reasons for transgressions

Some of the direct and indirect causes of transgressions were identified with the help of additional information from drinking-water assessors.

a. *E. coli* are introduced into the supply in the source water.

The turbidity of several zones, drawing from groundwater, was reported to increase following heavy rain. Such increases are likely accompanied by increased microbial loading. A decline in source quality combined with inadequate treatment, leads to the possibility of poor source water quality being one of the factors leading to *E. coli* transgressions in these zones.

b. Treatment is inadequate.

For the 'high transgression zones', three possible reasons for treatment inadequacy were reported: the absence of disinfection or satisfactory disinfection, the absence of filtration to remove turbidity from the water before disinfection, and poor treatment plant operation.

[5] Achievement is assessed each year so that over the four year period, each zone has a potential of four annual failures. For some zones the total of failures does not equal four because of achievement in some years.

Chlorination is not carried out in some supplies because the community does not want it. In these supplies UV irradiation is sometimes used as an alternative disinfectant. However, old UV units, which do not meet the requirements of the Standards, were in use in several failing zones. The water supplier has identified the need to improve the technology and plans to upgrade these systems. As the performance of the existing systems is potentially compromised during high turbidity episodes, improved filtration is also needed if the upgrade is to prove effective.

c. Failing infrastructure is allowing microbial contaminants into the distribution network.

In two of the 'high transgression zones' infrastructure (reservoir roof and aging asbestos cement pipes) requiring repair or replacement was identified as the possible reason for *E. coli* being detected in the distribution network. Contaminant ingress routes by themselves do not result in transgressions. In both cases there were also potential contaminant sources nearby: bird droppings on a reservoir roof and onsite sewage disposal that might allow contaminant entry through leaking pipes.

d. Water suppliers are not maintaining a disinfecting residual

Seventy percent of the 'high transgression zones' operate without a disinfecting residual, despite recurring transgressions. At least one of these communities has asked that their supply not be chlorinated.

Judging from the low *E. coli* concentrations reported, the level of contamination leading to *E. coli* detection can be low. Under these circumstances, a properly maintained chlorine residual is likely to be sufficient to eliminate many of the transgression events discussed in f (below).

e. Water suppliers have difficulty properly operating the water supply.

One drinking-water assessor noted that expenditure on treatment plant upgrades can result in a tight operational budget, with too few staff being available to attend the water supplier's several supplies during heavy weather. The assessor also considered that staff training was a casualty of the tight budget.

f. Water suppliers are unable to identify the source of the *E. coli* in the zone.

For several zones, drinking-water assessors reported that some transgressions resulted from low *E. coli* concentrations (near 1/100 ml) in the zone. *E. coli* was detected in only the initial transgressing sample; there were no detections in follow-up samples. This transient behaviour can make identification of the contaminant source difficult, which in turn hinders determining what remedial action is needed.

When faced with the transient appearance of contamination at low levels, some water suppliers were reported to tend to attribute the transgression to contamination of the sample or some factor other than the quality of the water. No doubt sample contamination, either in the field or the laboratory, occasionally happens. However, before a conclusion of sample contamination is reached a thorough investigation is needed. This should include determining how the sample became contaminated.

Monitoring is a tool used to establish the safety of a water supply. The value of monitoring is lost if its results are readily dismissed as sampling error. Sampler training should be considered when sample contamination is demonstrably responsible for transgressions. Following training, there should be little justification for sampling error being considered the reason for transgressions.

An alternative, less scientifically palatable explanation, for intermittent low-level transgressions is that the test method itself is at fault – false positive results. The requirement of the Standards for laboratories to use referee methods (or methods calibrated against referee methods) ensures that most laboratories are using the same or very similar methods. False positive results may occur from time to time, but do they occur frequently enough to contribute significantly to the high rate of transgressions in some zones?

Examination of the monitoring results from zones other than the 'high transgression zones' group suggests that false positives are unlikely to be the reason for the majority of intermittent transgressions. A zone's population should not influence the rate of false positive results. Consequently, the lowest levels of transgression found in large, well-managed, well-resourced zones, in which reasons for transgressions other than false positive results

have been minimised, should provide a measure of the rate at which transgressions in the 'high transgression zones' result from false positive tests.

To compare differences in transgression rates the percentage of monitoring samples that yielded detectable concentrations of *E. coli* in 12 larger zones was determined. In 10 of these zones, the percentage of transgressions was 0.16% or less; six recorded no transgressions. The remaining two (unchlorinated) larger zones recorded 0.64% and 0.90% of samples as transgressions. In contrast, 1.5–5.3% of monitoring samples from nine of the 10 'high transgression zones' were recorded as transgressions. The figure was 29% for the tenth zone. Based on these figures it is unlikely that false positives make a significant contribution to the transgressions occurring in the 'high transgression zones'.

Drinking-water assessor comments suggest that as well as the transient nature of some transgression events making event investigation difficult, discovering the source of contamination can be hampered by a lack of trouble-shooting skill on the part of the operational staff, or, it was suggested in one case, the will to investigate the transgression properly.

Corrective actions

When failure resulted from too many transgressions, corrective actions were considered by those completing the Survey to be adequate on 91% of occasions. The Standards (Figs 4.1 and 4.2) require investigation and remedial actions in response to transgressions. Investigation is needed to allow the cause of the transgression to be identified and actions to be taken to avoid transgressions recurring for the same reason. If corrective actions were adequate, the number of years in which 'high transgression zones' failed to achieve the Standards because of transgressions is surprising. The information provided by drinking-water assessors showed that the causes of transgressions were not always identified. It seems that several zones use temporary chlorination, or a boil water notice, to provide immediate, short-term health protection, and this is regarded as sufficient. However, the threat to the safety of the water remains while the cause is unidentified and remedial actions not taken.

3.1.3 NON-ACHIEVEMENT BECAUSE OF INADEQUATE MONITORING

Of the 10 'high transgression zones', only one was adequately monitored for the full four-year period. Six were inadequately monitored in two or three years. In the remaining three zones, inadequate monitoring occurred in one of the four years of interest. Given the poor level of monitoring in the majority of the 'high transgression zones' it is possible that the number of transgressions recorded for some zones was not an accurate reflection of the water quality. This is a concern for all zones in which inadequate monitoring was the result of too few samples being taken.

For the majority of zones, relatively minor technical factors were the reasons for the monitoring being inadequate; the number of samples taken in almost all zones was close to the minimum number required by the Standards. This suggests that inadequate monitoring in these zones resulted from a lack of care in meeting the detailed requirements of the Standards. In two zones, the number of samples taken was too low to be reasonably considered an oversight.

Monitoring was better in the 16 'moderate transgression zones'. Half of these zones were adequately monitored for the full four-year period.

3.2 OUTLOOK FOR *E. COLI* ACHIEVEMENT

The information in Table 2 is presented to help in assessing the progress being made to improve achievement in the 'high transgression zones'. It identifies the actions taken, or planned, to try to reduce the likelihood of transgressions and suggests what these actions may mean for future *E. coli* achievement, based on the data available to 30 June 2014.

Eight of the 10 zones had taken, or were planning, steps to reduce the likelihood of detecting *E. coli*. In half, UV disinfection was planned, but not implemented. In the two zones in which investigation of a transgression was recorded as a corrective action, transgressions were still occurring despite UV treatment already being in place (although the unit may not have met the specifications required by the Standards). The installation of an efficacious disinfection process to ensure the quality of the water entering the distribution zone is a key step to

the improvement of the performance of these zones. However, this step alone may be insufficient if pathways for post-treatment ingress of contaminants exist.

Table 2 Summary of corrective actions and the likely effect on E. coli *non-achievement in the zone for the 'high transgression zones'*

Zone	Actions taken, or planned, to reduce the likelihood of continuing non-achievement	Outlook
A	Investigation of transgressions	Sources of contamination found, but transgressions continue. The supplier is avoiding the introduction of chlorination. Continued non-achievement.
B	Investigation of transgressions	Transgressions still occur. Continued non-achievement.
C	New UV unit (2012-13) and ceramic filters installed	Old reticulation still a potential cause of transgressions. Supply operated on very limited budget. Intermittent non-achievement likely.
D	New secure source 2012	New source reduces the likelihood of contamination arising from the source, but the leaky reticulation still presents a possible pathway for contaminant ingress. Intermittent non-achievement likely.
E	New UV unit with filtration planned Presently chlorinated*	Likely to improve water quality provided filtration achieves adequate turbidity reduction. Continued non-achievement until the upgrade is operational.
F	Reservoir replaced New UV unit planned	Old reservoir may have been connected with earlier transgressions. Continued non-achievement until the upgrade is operational.
G	New UV unit planned	Continued non-achievement until the upgrade is operational.
H	MIOX unit (2013-14)	Marked improvement, but continuing problems with chlorine dose control. Continued non-achievement until a satisfactory residual can be maintained.
I	New UV unit with filtration planned	Continued non-achievement until the upgrade is operational.
J	Presently chlorinated* (2012-13). Plant upgrade planned.	Chlorination should be reducing the likelihood of non-achievement. Ability to achieve the Standards should be improved with the upgrade.

* Temporary chlorination until upgrades are completed

4 CHEMICAL NON-ACHIEVEMENT

4.1 FINDINGS AND DISCUSSION

During the 2013-14 year, 35 zones in the primary dataset (341 zones), failed to achieve the chemical requirements of the Standards. Eighteen of these zones failed in either all years (12 zones), or 2013-14 and two other years (6 zones). For brevity, this group of 18 is referred to as the 'high failure zones'.

An excessive number of transgressions was the primary reason for most (64%, 43/67) of the annual failures to meet the chemical standards in the 'high failure zones'. Inadequate monitoring was the sole reason for non-achievement of the Standards in 36% (24/67) of cases, a substantially larger fraction than was the case for *E. coli* achievement. When the chemical standards were not achieved because of transgressions, corrective actions to address the transgressions were considered adequate in 23% (10/43) of failures.

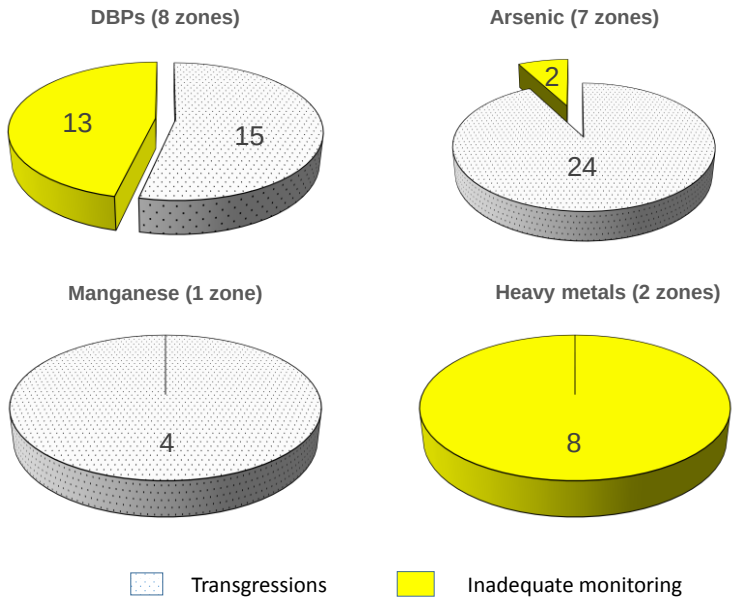
The determinands represented in the 'high failure zones' fall into one of four groups: heavy metals, disinfection by-products, arsenic and manganese. These determinands were assigned as Priority 2 determinands in more than one zone, except for manganese.

4.1.1 NON-ACHIEVEMENT BECAUSE OF TRANSGRESSIONS

Transgressions

Figure 1 shows, for each determinand group, the combined number of years[6] in which the chemical standard was not achieved because of transgressions or inadequate monitoring.

Figure 1 *Number of failing zones for each Priority 2 determinand group (brackets) and the relative contributions of transgressions and inadequate monitoring to failure*



The percentage of monitoring samples that transgressed the MAV ranged from 28–80%. This is in marked contrast to the sampling statistics for *E. coli* in which the percentage of monitoring samples with transgressions ranged from 1–29%.

A chemical determinand can be present in the water in a zone because it is present in the source water (and is not removed by treatment), is produced or introduced during treatment or is derived from the zone's construction materials. These sources of the determinand generally result in it being present in the zone all, or almost all, of the time, albeit at fluctuating concentrations. The magnitude of the fluctuations will depend on the determinand (eg, disinfection by-products may vary considerably in concentration). Nevertheless, if the typical determinand concentration is near, or exceeds, the MAV, it is likely that a high percentage of monitoring samples will show exceedences of the MAV.

The situation is different for *E. coli*. This indicator bacterium may be found in monitoring samples because it was present in the raw water and passed through treatment barriers, or because of a failure in a post-treatment barrier (such as leaking pipes). Both entry paths are prone to much greater variability than those by which chemical determinands may enter a zone. A source of *E. coli* and a route into the reticulated water may arise intermittently. Consequently, the percentage of monitoring samples showing *E. coli* transgressions is often correspondingly low.

[6] This is the sum of the number of years each zone did not achieve the Standards because of transgressions or inadequate monitoring. The maximum total possible is the number of zones with the assigned determinand times four. The totals do not always sum to this because of years in which a zone achieved the Standards.

Identifying the reasons for chemical transgressions is more straightforward than identifying the reasons for *E. coli* transgressions. The zones with arsenic transgressions had no treatment that could remove the arsenic naturally present in the raw water. Disinfection by-product transgressions may have resulted from precursors in the raw water being too high and concomitantly the treatment processes being unsuitable for removing precursors, the operators being unable to optimise precursor removal or a combination of these factors.

Nothing can be said about the heavy metal transgressions as the zones with heavy metals assigned as Priority 2 determinands were not monitored.

Corrective actions

Corrective actions to address non-achievement of the chemical standards can present difficulties for a water supplier. This is borne out by the fact that when corrective actions were needed, they were considered adequate in only 23% of cases.

The concentrations of both arsenic and disinfection by-products, which were the determinands leading to the majority of failures because of transgressions, cannot generally be reduced by simple, inexpensive treatment. Arsenic can be removed by conventional treatment provided the arsenic in the water is in a suitable form. Water supplies that do not operate a treatment process capable of removing arsenic, face the expense of a treatment plant upgrade or searching for, and developing, a new low-arsenic source.

The precursors to the formation of disinfection by-products are naturally-occurring substances. Their concentration in the source water, and consequently the levels of by-products formed, can be variable. Water suppliers having to disinfect their water cannot dispense with disinfection. As a result, if a new, low-precursor source cannot be found, the only effective corrective action is to remove the precursors from the existing source water before disinfection. Where the treatment processes in use are capable of reducing the precursor concentration, process 'tuning' to optimise removal may be needed. To do this the water supplier has to be able to afford advice, the up-skilling of operators and possibly new monitoring instrumentation. Where a suitable treatment process for precursor removal is not already in place, a plant upgrade is required. Whichever situation exists, effective mitigation can be expensive.

For chemical determinands the possibility of corrective actions that immediately protect public health (as a boil water notice does for microbial contamination) does not generally exist. Taking corrective action for chemical transgressions occurs over a much longer period, involving planning, budgeting and eventual implementation. Although a long period may be required for implementing a corrective action for a chemical determinand, the potential consequences for public health of the delay are not as great a concern as those resulting from delays in addressing microbial contamination. The MAVs for chemical determinands are set to provide protection against adverse health effects over a lifetime of exposure.

4.1.2 NON-ACHIEVEMENT BECAUSE OF INADEQUATE MONITORING

Inadequate monitoring can compromise a water supplier's ability to make an informed decision about the need for corrective action. It also prevents assessment of the public health risk posed by a chemical determinand in a water supply.

Inadequate monitoring led to 36% of the cases of non-achievement of the chemical standards. In addition, over the four year period, the monitoring in 11 of the 18 'high failure zones' was inadequate during at least one year when transgressions were the primary reason for failure. Accordingly, even in the absence of transgressions, the zones would still have failed because of poor monitoring. Both of these statistics indicate that as well as taking action to avoid chemical transgressions, water suppliers need to ensure they have established, and are adhering to, a sampling schedule that meets the requirements of the Standards.

Monitoring was inadequate for five zones because no samples were taken for three or more of the four years. This is a different situation from that where inadequate monitoring might be considered unintentional because slightly too few samples were taken, or there was a minor technical shortcoming. No monitoring infers a clear policy decision by the water supplier.

For small supplies or territorial authorities with scarce resources, a policy decision not to sample for determinands that are expensive to test for, such as disinfection by-products, is understandable. They may have already collected data to show that transgressions are an ongoing problem, which they can do nothing about without major expense. If they conclude that further monitoring is not telling them anything more than they already know, they may consider that money spent on monitoring could be better used in trying to provide a solution to the problem. If this is the case, these zones will continue to fail.

More difficult to understand was the situation of the two zones that have been non-achieving for four years because of inadequate monitoring of heavy metals. These metals were almost certainly corrosion-derived. If this had been confirmed, by a very brief monitoring programme (three monthly samples), the metals could have been reclassified as Priority 3 determinands and the need to monitor would have ceased. Furthermore, the Survey returns from both water suppliers showed that consumers were being notified of the need to flush the tap before use. Therefore, the water suppliers were meeting their obligation to manage the health risk associated with corrosion-derived metals.

4.2 OUTLOOK FOR CHEMICAL ACHIEVEMENT

The instigation of satisfactory monitoring where there has been none before will remove inadequate monitoring as a hurdle to achieving the chemical requirements of the Standards. Achieving this will depend on persuading some territorial authorities to change what appears to be a 'no-sampling' policy. In zones where some monitoring was undertaken (but it was inadequate) more care in sample scheduling should contribute to improved levels of chemical achievement. In both of these situations it is possible that improved monitoring may increase the likelihood of encountering transgressions.

The zones with known disinfection by-product transgressions but which had not taken corrective measures, will continue to fail the chemical standards. At two zones there had been changes to treatment, which offered the possibility of eliminating transgressing concentrations of disinfection by-products. The success of the treatment changes will hinge on the nature of the upgrades and the knowledge and skills of the operators.

The zones with arsenic transgressions will continue to fail chemically unless a new source with low arsenic concentrations is found, or funding for treatment capable of removing arsenic obtained.

At the one zone monitoring for manganese, a new treatment plant had been commissioned and had shown encouraging results, which showed that the zone should achieve the Standards in future.

5 PUBLIC HEALTH SIGNIFICANCE

While this study was primarily concerned with understanding why non-achievement occurred and what was being done to improve the performance of non-achieving supplies, the ultimate reason for ensuring supplies achieve the Standards is the protection of public health.

Non-achievement of the Standards does not necessarily imply a direct or immediate threat to public health. In general, any public health risk associated with inadequate monitoring is likely to be inconsequential. However, there is an indirect public health risk associated with inadequate monitoring when it results in a water supplier being unaware of a contamination event.

The public health risk associated with zones in which *E. coli* was detected is difficult to assess. *E. coli* itself (unless it is a pathogenic strain) is not harmful, but its presence in water shows that the water has been in contact with faecal matter, and may contain pathogens. Consequently, a transgression indicates a potential risk to health. The more frequently transgressions occur in a zone, the greater the microbiological risk to the consumer. As a first approximation, the 'high transgression zones' presented a greater risk to the health of their residents than the 'moderate transgression zones' because of the greater number of years in which transgressions had led to non-achievement of the Standards. The risk to residents in zones in which appropriate corrective actions have been taken will be lessened once these steps take effect.

The public health risk associated with chemical determinands is more readily assessed than the risk from microorganisms because the concentration of the health-significant determinand itself is measured in the water.

Again, the greatest risk to the health of residents exists where the determinand's concentration is highest and transgressions occur most frequently. The nature of the chemical determinand also has a bearing on the level of risk. Of the chemical determinands monitored, arsenic represents that greatest public health concern. This is partly because the arsenic concentration in some zones exceeds the MAV constantly or frequently. The health risk is further compounded by the fact that the cancer risk associated with an arsenic concentration equal to the MAV is 1 in approximately 1700, rather than the risk for most other carcinogens of 1 in 100,000.

As with microbiological risk, the chemical risk in some zones that have failed the chemical standards is being managed by corrective actions: treatment up-grades or the search for new sources.

6 CONCLUSION

The conclusions below are based on the datasets reviewed in preparing this report. Future review of the full set of data from the Survey may provide further insights into the reasons for non-achievement of the Standards and how levels of achievement might be improved.

6.1 KEY FINDINGS

a. Too many transgressions during a reporting year was the prime cause of the non-achievement of the Standards for both *E. coli* and chemical determinands.

b. Despite excessive numbers of *E. coli* transgressions repeatedly causing non-achievement in some zones, corrective actions to address the transgressions were, in the great majority of cases, considered adequate by those completing the Survey.

c. The great majority of corrective actions in response to chemical transgressions were considered inadequate. Effective corrective actions for addressing chemical transgressions present water suppliers with a difficult problem because they cannot generally be implemented immediately and they can be expensive.

d. Treatment plant upgrades to UV irradiation was planned for many of the zones in which there had been repeated *E. coli* transgressions. This should provide a barrier to pathogens entering the distribution zone, but provides no means of controlling post-treatment bacterial contamination of the water.

e. Improvements in levels of *E. coli* and chemical achievement can be expected when planned treatment upgrades are commissioned and teething troubles being presently experienced are overcome. The ability and willingness of water suppliers to fund the necessary improvements in their water supplies will determine the extent and rate at which levels of achievement will improve.

f. The benefits of water supply upgrades may not be fully realised if capital expenditure cannot be matched by appropriate levels of operational expenditure, eg, staffing levels and staff training.

g. Some water supplies appear to have made a decision not to carry out the monitoring required for achievement of the Standards, particularly for chemical determinands. This may be because of the expense of the analyses. Non-achievement in these zones can be expected to continue.

6.2 IMPROVING LEVELS OF ACHIEVEMENT OF THE STANDARDS

The steps suggested below, in relation to achievement of the *E. coli* and chemical standards, follow from the study's findings.

a. Ensure water safety plans include a requirement to investigate the cause of transgressions and that measures to address the causes are implemented.

- The need for investigation of *E. coli* transgressions is made clear in the Standards.

- Good evidence is needed before concluding that sample contamination is the reason for *E. coli* detection in a sample. When sample contamination is the cause, actions, such as sampler training, need to be taken to prevent recurrence.

- Water suppliers should seek help from their drinking-water assessor if they encounter difficulties with their investigation.

b. Where source water turbidity may rise with rainfall, ensure filtration is installed as part of treatment plant upgrades to guard against the efficacy of the disinfection processes being compromised. This should ensure that the water quality leaving the treatment plant is satisfactory.

c. Where repeated non-achievement of the *E. coli* standards occurs because of transgressions, take steps to maintain a disinfecting residual in the zone.

    - The relatively inexpensive measure of introducing a residual disinfectant into zones that presently contain no residual provides a means of helping to control the risk to public health of low-level post-treatment contamination.

    - Communities that are opposed to chlorination need to be informed of the potential consequences of this decision to ensure they are fully aware of its ramifications.

ACKNOWLEDGEMENTS

The authors are grateful to the drinking-water assessors and water suppliers who provided additional background information concerning water supply transgressions, the Ministry of Health for funding the study, and Ministry and ESR staff who reviewed drafts of the report and this paper.