

**A National Drinking-Water Quality Survey of
New Zealand Rural Schools 2023/2024**

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**GNS Science Consultancy Report 2023/106
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EXECUTIVE SUMMARY

The Ministry for the Environment and Ministry of Education commissioned GNS Science (GNS) to coordinate and report on the first nationwide groundwater quality testing programme of rural school drinking-water supplies. Declining groundwater quality has been reported across rural New Zealand, with specific concerns around increasing nitrate levels due to farming and other human-induced activities. However, there are knowledge gaps around the level of water contaminants, such as nitrate nitrogen in privately owned bores, as many are not routinely tested (Ministry for the Environment 2023). This national survey serves as a benchmark assessment of source-water quality at 245 rural schools located across the North Island and South Island, as well as Pitt Island, which supplies its own drinking water.

Collected samples were either untreated groundwater from bores, springs and surface sources (such as creeks and rivers) or alternatively treated tap water where schools were unable to sample prior to treatment. This report outlines the design, process and testing protocols used; summarises the collected water-quality results; evaluates them against the Water Services (Drinking Water Standards for New Zealand) Regulations (NZDWS) (2022) and Aesthetic Values for Drinking Water Notice (AVDWN) (Taumata Arowai 2022a) and provides recommendations.

The project was co-designed between GNS, the Ministry for the Environment and the Ministry of Education Water Services Team to:

- Identify eligible rural schools that use groundwater as a primary or back-up source for their drinking water.
- Select 29 suitable determinands¹ to comprehensively assess rural school water quality, where 23 out of 29 measured determinands have regulated Maximum Acceptable Values (MAV) or Aesthetic Value (AV) limits.

GNS undertook an engagement survey with 288 schools to confirm participation eligibility and capture water-supply management concerns. Around 27 schools were excluded due to having non-groundwater drinking-water sources or due to the impracticality of testing. GNS then coordinated the dispatch of testing kits to the eligible rural schools. In total, 245 schools returned samples for analysis.

Each school sampled its own drinking water and dispatched the samples to Hill Laboratories in Hamilton for testing. Analytical results were sent to GNS, who in turn provided each school with a short report summarising the quality of its drinking water sample. Schools with levels of drinking-water determinands above the MAV were contacted by the Ministry of Education, which undertook further testing, followed by support to mitigate the exceedances where required.

Most of the 245 water samples from rural schools met the drinking-water standards for the selected MAV (outlined in the NZDWS¹) and/or AV determinands (outlined in the AVDWN²). However, 59 water samples (24.1% of schools sampled) did not fully meet these requirements, with one or more exceedances of the MAV or AV.

1 <https://www.legislation.govt.nz/regulation/public/2022/0168/latest/whole.html>

2 <https://www.taumataarowai.govt.nz/assets/Uploads/Rules-and-standards/Taumata-Arowai-Aesthetic-Values-for-Drinking-Water-2022.pdf>

Key findings of the national testing include:

- Six drinking-water determinands exceeded the NZDWS MAV at 30 schools: arsenic (3 schools), *Escherichia coli* (20 schools), lead (5 schools), manganese (2 schools), mercury (1 school) and nitrate-N (1 school).
- Five drinking-water determinands were between ½ MAV and MAV at 42 schools: arsenic (6 schools), copper (3 schools), lead (14 schools), manganese (8 schools), nitrate-N (20 schools).
- Five drinking-water determinands exceeded AV at 48 schools: hardness (12 schools), iron (31 schools), manganese (28 schools), turbidity (21 schools) and zinc (2 schools), while pH was below the lowest recommended value of pH7 for 79 schools and above the highest recommended value of pH8.5 for 11 schools.
- Of the regulated MAV and AV determinands, ammonia, antimony, boron, cadmium, chloride, chromium, fluoride, nitrite, sodium, sulphate and total dissolved solids consistently measured below ½ MAV or AV in the survey, indicating that they were within acceptable limits and posed no cause for concern.
- Most school drinking-water treatment systems consist of filtration followed by UV light disinfection, which does not effectively remove some MAV determinands such as arsenic, lead, mercury and nitrate; therefore, these appear at levels above MAV thresholds in treated tap water.
- For rural communities, the biggest future threat to groundwater quality is nitrate contamination (Rogers et al. 2023; GNS Science [2024]³). Nitrates are now a determinand of significant public concern in some rural regions. While most urban school drinking-water nitrate concentrations are less than 1 mg/L nitrate-N, 100 rural schools (41%) had nitrate values above 1 mg/L nitrate-N and 21 schools (8.6%) had nitrate values above ½ MAV (5.6 mg/L nitrate-N).

This survey represents a snapshot of rural school water quality between October 2023 and April 2024. Determinand levels in groundwater and surface water vary seasonally according to rainfall, so that more comprehensive testing is required to identify longer-term trends for effective monitoring of water quality. Furthermore, this report should not be used to comment on rural drinking-water compliance, as the data includes untreated groundwater and surface-water samples and may contain determinands that are effectively removed by treatment. However, this survey identifies contamination risks and threats for rural drinking water and the need for robust water-treatment systems to mitigate existing and future determinand contamination threats.

A series of recommendations are made below for schools where treated groundwater sampled at the tap had levels of determinands that exceeded ½ MAV or did not meet minimum standard requirements outlined in the NZDWS (2022) or AVDWN (Taumata Arowai 2022a). These recommendations align with the Ministry of Education's water-quality risk-mitigation approaches.

3 <https://www.gns.cri.nz/research-projects/nitratewatch/>

1. For schools with untreated source water determinands at levels **above $\frac{1}{2}$ MAV**:
 - Ongoing regular monitoring of these determinands in untreated source water should occur to ensure that levels do not exceed MAV.
2. For schools with untreated source water determinands at levels **exceeding MAV**:
 - These schools should be required to undertake monitoring of untreated source water and treated tap water, i.e. monthly, to confirm treatment is effective by ensuring that the determinand levels in the drinking water meet the drinking-water standards.
 - Alternative drinking water sources should be supplied to any school with treated water determinand levels exceeding MAV until effective treatment or mitigation is in place.
 - Investigate the cause of the determinand exceedance, assess risk and notify appropriate agencies of the mitigation implemented.
3. For schools with untreated source water determinands at levels **exceeding AV**:
 - These schools are recommended to check the efficiency of their water treatment and consider implementing treatment if water quality is impacting on disinfection effectiveness or the palatability of the drinking water.
 - If appropriate, schools should consider alternative drinking-water sources if water quality is impacting on drinking water acceptability until such time as the AV exceedances have been mitigated.
4. The recommendations in this report highlight the need for consistent drinking-water quality testing for all rural schools as required under the Water Services Act 2021, including:
 - Quarterly testing of all determinands exceeding $\frac{1}{2}$ MAV or AV thresholds in both untreated source water and treated tap water **at all schools supplying their own drinking water** to ensure water-treatment effectiveness.
 - A full Routine Water Profile should be run on **all rural school untreated source water every three years** to monitor for changes in contaminant levels in groundwater or surface water.

1.0 INTRODUCTION

Water quality for (rural) domestic self-supplies is a key data gap which limits our understanding of the extent of any health impacts. (Ministry for the Environment 2023)

Universal and equitable access to safe drinking water is a basic human right (United Nations, 2010; World Health Organisation 2016). The New Zealand government, primarily via Taumata Arowai on advice from the Ministry of Health (2017), set standards and regulations to protect all New Zealanders through the New Zealand Drinking Water Standards (NZDWS) (Water Services Drinking Water Standards for New Zealand Regulations 2022). Town drinking-water supplies are carefully monitored and maintained to these standards by centralised water-supply providers delivering customers a high standard of water quality via a comprehensive distribution network within the supply boundary. Conversely, small rural drinking-water suppliers face a growing range of challenges and issues, including declining source-water quality in some regions, alongside fewer regulatory requirements around quality assurance and testing than larger water suppliers serving urban regions (Taumata Arowai 2022b).

In recent times, growing land-use intensity and climate change has seen a decrease in rural groundwater quality due to a diverse range of contaminants, derived from farming, horticulture, industry and other activities that discharge pollutants into groundwater receiving environments (Baker 2017; Ministry for the Environment 2023). Nitrate levels in rural water have reached concerning levels in some rural areas. Recent testing of nitrate levels in private rural bores over the last two years undertaken as part of NitrateWatch⁴, a community science initiative, shows that some regions in New Zealand are significantly affected by above-MAV levels of nitrate due to the impact of farming intensification.

In parallel, recent overseas studies have proposed an association between nitrate levels in drinking-water supplies and bowel cancer (Schullehner et al. 2018) and increased risk of specific cancers and birth defects when nitrate is ingested under conditions that increase formation of N-nitroso compounds (Chambers and Hales 2021; Chambers et al. 2022; Richards et al. 2022). The regulatory limit for nitrate in public drinking-water supplies was set over 40 years ago to protect against infant methemoglobinemia, but other health effects were not considered at that time. There is growing attention and interest at central Government level to ensure that the nitrate MAV is set at an appropriate level (Ministry for the Environment 2023). However, the evidence base was not deemed conclusive with respect to whether the relationship is causal or coincidental and, at the time of writing this report, the guidance from the Office of the Prime Minister's Chief Science Advisor is to monitor and assess compliance with the current MAV (Prime Minister's Chief Science Advisor 2022 [revised 2023], and references therein).

The challenges of monitoring and regulating rural drinking-water supplies are significant and has been overseen by Taumata Arowai since 2021, which is implementing stepwise changes in legislation to better regulate smaller water suppliers. However, the onus on testing and monitoring of rural drinking-water supplies still falls on water suppliers and private bore owners (Taumata Arowai 2022b). Bore registration and routine testing of water supplies is a critical pathway to ensuring safe drinking water. However, domestic self-supplies are currently not subject to any monitoring or reporting regime, creating a data gap and risk to public health.

4 <https://www.gns.cri.nz/research-projects/nitratewatch/>

A key goal of this study was to use rural school drinking-water supplies as a proxy for rural New Zealand drinking-water supplies to better understand rural water-quality issues and identify trends and future risks that may affect small water suppliers and private bore owners.

The Ministry of Education Water Services Team supports around 450 rural schools across New Zealand that operate their own water supply. While most schools rely on council or community water-scheme supplies, around 20% of schools (450) manage their own water sources, such as roof-water collection systems, bores or springs, to self-supply their school drinking water. Under the Water Services Act (2021), 95% of self-supplied schools are registered with Taumata Arowai as water suppliers and have responsibilities to ensure that they provide a safe drinking-water supply.

Currently, the Ministry of Education requires self-supplied schools to test their treated water monthly for *Escherichia coli* (*E. coli*) and Total Coliforms. With the setting of new Drinking Water Quality Assurance Rules (Taumata Arowai 2022b), most rural schools as registered water suppliers are required to comply with a wide range of new quality-assurance requirements, including expanded testing for a more comprehensive suite of determinands. In consultation with the regulator, the Ministry of Education is working with schools to assist them to comply with the new requirements. This includes investing in new data monitoring and management tools, guidance on enhanced source and treated water testing and assistance to complete critical maintenance, as well as funding upgrades of school water-supply infrastructure.

Groundwater is vulnerable to contamination, so active risk management in terms of source water risk-management plans and multi-barrier preventative measures are required across the entire drinking-water system. Taumata Arowai ([2024]) outlines six principles for drinking-water safety (Table 1.1) that motivate this first-ever national study of rural school drinking water.

Table 1.1 The principles of water safety as outlined by Taumata Arowai ([2024]).

Principles	Overview
A high standard of care must be embraced	As unsafe drinking water can cause illness or death, all those involved in supplying drinking water must embrace a high standard of care.
Protection of source water is of paramount importance	The risks to sources of drinking water must be well understood and managed, as the protection of source drinking water provides the first barrier against drinking-water contamination and illness.
Maintain multiple barriers against contamination	Drinking-water systems must have multiple robust barriers against contamination. No single barrier is effective against all sources of contamination, and barriers can fail at any time.
Change precedes contamination	As contamination is almost always preceded by change of some kind, water suppliers must monitor and respond to any changes as part of their due diligence.
Suppliers must own the safety of drinking water	Drinking-water suppliers must manage the risks to their water-supply operation to ensure that they supply safe drinking water to their consumers.
Apply a preventive risk management approach	Drinking-water suppliers should conduct a systematic assessment of risks throughout their drinking-water supply. This will provide the best protection against waterborne illness.

1.1 Study Brief

The Ministry for the Environment and the Ministry of Education commissioned GNS Science (GNS) to:

- Undertake a national drinking-water quality survey of rural schools utilising groundwater.
- Identify any gaps in the determinand suite used in routine school water testing.
- Provide recommendations on future monitoring requirements for at-risk regions to ensure that all non-reticulated rural schools' drinking water sourced from groundwater meets the NZDWS standards.

The over-arching objective of this project was to collect meaningful data on the drinking-water quality of small water suppliers utilising groundwater sources. This National Rural School Drinking Water Survey was the first-ever survey of its kind to comparatively test and assess 29 determinands potentially present in rural school drinking-water groundwater supplies, identifying regional- and national-scale baselines for rural schools and identifying suppliers requiring further support to ensure that their drinking water meets national drinking-water standards. By selecting a rural school network, the survey doubles as a generalised rural groundwater study, having spatial coverage across all the main rural areas within New Zealand.

This study focuses on determinands that are not routinely tested by monthly school compliance testing and also examines determinands (such as dissolved metals, nitrates, nitrites, etc.) that are not easily removed by existing treatment processes installed to ensure the quality of groundwater-sourced drinking water.

It is important to note that the results of this study represent only a snapshot of rural school water quality from October 2023 to April 2024 and should not be used to report on rural drinking-water compliance, as it includes analysis of both untreated and treated groundwater and surface-water samples.

1.2 Report Content

This report has a further eight sections that:

- describe the project background rationale, design and methods (Section 2);
- provide a description for each of the selected determinands, its origin or source, threshold limits of concern and any health risks associated with elevated levels (Section 3);
- present the engagement survey and results (Section 4);
- present the water determinand results, including distribution, range and exceedances (Section 5);
- undertake a determinand risk assessment and prioritise drinking water determinands that require routine monitoring (Section 6);
- outline the challenges encountered during this study (Section 7);
- recommendations (Section 9); and
- conclusions (Section 9).

2.0 METHODS

Schools using rural drinking water, sourced from groundwater or surface water (springs, creeks, etc.), were identified using a national database of schools held by the Ministry of Education. This was able to provide data on the water source and number of users, as well as contact details and addresses for the relevant schools. The Ministry also provided some support with engaging with schools to encourage and facilitate their participation in the study. The initial database consisted of 275 schools primarily using groundwater (251 schools on bores, 24 schools using spring or creek water) and a further 13 schools using groundwater as a back-up supply.

2.1 Study Design and Timeframe

The study was initially co-designed between GNS and the Ministry for the Environment in August 2023, then broadened to include the Ministry of Education in September 2023, which provided supplementary funding to widen the determinand range and supply extra human resources. The Water Services Team (Ministry of Education) offered strong support, providing data and logistics to identify and engage rural schools in the study. Before engagement occurred, a low-risk ethics assessment was undertaken and peer-reviewed by the GNS Social Sciences team to ensure that participant details and results were protected and kept confidential.

The project was designed over several stages:

- **September–October 2023:** Eligible schools identified from the Ministry of Education dataset as using groundwater as a primary or back-up source of drinking water were contacted via email and asked to complete a short online engagement survey to identify their suitability and willingness to participate. A selection of determinands was screened by the Ministry for the Environment, the Ministry of Education and GNS. The selected suite included the Routine Drinking Water testing suite offered by Hill Laboratories (determinands listed in Appendix 4), with the addition of ammonia, antimony, cadmium, chromium, fluoride, mercury and nitrite.
- **November 2023 – January 2024:** Each participating school received a water sampling kit to take its own water samples. If required, additional support to collect and send the sample was provided.
- **December 2023 – April 2024:** Collection and analysis of drinking water from 245 rural schools across New Zealand. This task involved preparation of sampling kits and development of sampling guidance material by GNS. Sample collection and dispatch to the laboratory was undertaken by individual schools. All samples were analysed at Hill Laboratories in Hamilton.
- **December 2023 – April 2024:** Provision of individual water-quality reports detailing the results and any exceedance concerns with regards to the NZDWS, prepared by GNS and issued to all participating schools.
- **June 2024:** GNS provision of a report to the Ministry for the Environment and the Ministry of Education synthesising the data collected from the participating schools and summarising the drinking-water quality of each, with a comparative drinking-water quality assessment based on the determinands tested.

2.2 Survey Design and Engagement

Communication collateral, including an engagement survey and participant information sheet, was designed by GNS (Appendix 1) to introduce the project to schools and confirm water supply information in the Ministry of Education database. To confirm participation, schools were required to respond to a range of questions about their water supply and its management.

While the focus of the survey was on the drinking-water quality supplied to rural schools, it was also important to factor in that school facilities (such as school halls, classrooms and libraries) are frequently used as community meeting hubs for various activities.

Survey questions were selected to provide key context information for drinking-water supplies on:

- The source of groundwater and availability of alternate supplies, as vulnerability to contamination varies between supply types. For example, groundwater sourced from deep, confined aquifers is less likely to contain contaminants.
- The number of supply users and possible additional users, e.g. local community events.
- The awareness of school personnel regarding regulatory water testing and handling of the results.
- The vulnerability of a water supply under an extreme natural hazard event, considering the importance of schools in local communities as a community gathering point. Rural schools are often situated in remote regions to enable children within the catchment to attend school without the need for a long or complex journey to and from its location. Given the remoteness of some schools, there are a range of natural-hazard threats that can affect school drinking-water supplies.

The survey was first sent out to all schools listed in the database on 18 September 2023, with three further reminders sent 16 October, 1 November and 11 November 2023. While most schools replied within this timeframe, a smaller number of schools required individual follow-up to confirm their participation (Table 2.1). Three schools declined to participate, and 21 schools were found to be ineligible, as they did not use groundwater as a drinking-water source. A further six schools were not required to participate, as they were on town supply or had recently received upgrades to their water-supply systems that included changing to rainwater as their primary drinking-water source. Once schools had completed the survey, which also acted as an agreement to participate, this triggered the subsequent sending of a sampling kit from Hill Laboratories.

Table 2.1 Breakdown of 288 school responses to the initial invitation survey.

School Response	Number	Outcome
Responded	245	Signed up to participate
Declined	3	Declined to participate
Removed	21	Completed the survey and, based on their responses, were deemed ineligible, i.e. no groundwater use
Bounced emails	6	Email contact was not possible
Do not contact	6	Schools were identified as not needing to participate
No response	7	Did not respond to three emails or other contact attempts
Total	288	Number of rural schools identified by the Ministry of Education as potential participants

2.3 Sample Kits and Water-Source Identification

Due to the large nature of this survey, it was not possible to send a scientist to every school to sample source or tap water. The project relied heavily on schools receiving the sample kit and self-sampling for the survey. Sampling kits containing three water bottles and chiller pads were mailed out by Hill Laboratories to each school to collect their water (Figure 7.2). Sampling kits were sent out from November 2023 until February 2024. Three bottles were included in the kit to sample for:

- *E. coli* – a 400 mL sterile plastic bottle with thiosulphate preservative.
- Routine water parameters – a 500 mL polyethylene bottle with no preservative.
- Heavy metals – a 100 mL polyethylene bottle with nitric acid preservative.

Each school received a sheet with standard water-sampling instructions provided by Hill Laboratories (Appendix 2) describing how to fill the bottles from the bore or spring source prior to any water treatment, and the importance of chilling the sample for shipping to ensure that the untreated water-source quality could be accurately assessed. If samples arrived at the testing laboratory above 10°C, this was noted on the sample submission form and results report.

Schools were asked to sample directly from the bore to provide an untreated source sample, confirming the suitability of any pre-treatment steps currently in place. Untreated source-water testing identifies supply risk should there be no treatment or should treatment fail. It also serves as an indicator of regional groundwater health and the state of the environment. It was not always possible for schools to sample untreated source water, and some schools submitted tap-water samples taken post-treatment. For the purposes of this report, drinking water from rural schools is classed into three water-source types; bore water, surface water and treated tap water.

Bore water– untreated source water is sampled directly from the groundwater bore prior to any treatment.

Surface water – comprises water sampled from a spring pool or outlet, creek water or river water. It is classified separately from bore water, as it is more exposed to surface contamination and so may contain higher levels of contaminants.

Bore and surface water – provides an overview of the untreated source water quality. *It is assumed that this water is not filtered or pre-treated before sampling.*

Treated tap water – provides an overview of the post-treatment water quality and assesses treatment efficiency and suitability. *It is assumed that this water is treated via cartridge filtration and UV disinfection prior to sampling.*

2.3.1 Sample Collection

Schools were requested to fill the bottles according to sample-collection instructions provided in the kit and send the samples back on the same or following day, keeping the samples chilled to below 10°C where possible. Usually caretakers, principals or water contractors were able to sample untreated bore water or surface water, given their familiarity with the water supply system. However, in some instances, due to the absence of a sampling tap at the bore or access to the bore chamber or housing, provided samples were taken from point-of-use taps within the

school. Treated tap-water samples were usually taken by school administrators, such as office staff, from a kitchen tap or school drinking-water fountain due to their lack of familiarity with the source-water supply system. Water bore-sampling locations or drinking-water taps were purged for a few minutes before sample collection and samples placed in a courier box for shipping to Hill Laboratories in Hamilton within 24 hours of sampling.

If samples were received by Hill Laboratories above 10°C and/or more than 24 hours after sampling, the sample was still analysed, contrary to monthly school drinking-water testing, where any samples not arriving chilled (<10°C) and within 24 hours are excluded from testing. This criterion is based on the ability of *E. coli* and Total Coliforms to multiply in the sample during this time and return an excessive count. Hill Laboratories provided analytical results to GNS to re-direct to the Ministry for the Environment, the Ministry of Education and individual schools.

2.4 Laboratory Testing Methods

Water determinands were analysed by Hill Laboratories according to standard water-testing methods. Samples testing below Limits of Detection (LOD) are indicated by <LOD, where LOD represents the minimum machine detection limit of a determinand. A list of these methods and their detection limits is included in the summary of methods supplied by Hill Laboratories in Appendix 3.

2.5 Reporting of Results

Hill Laboratories provided electronic copies of each sample submission form and a *.pdf* and *.csv* file of the analytical results within 10 days of sample reception. A unique laboratory ID number was linked to each school. Official results were provided by Hill Laboratories to GNS. The data were entered into a master database, and any MAV or AV exceedances were reported to the Ministry of Education, which then contacted schools to discuss the exceedance. Individual school reports were generated by GNS and sent to the school office administration and principals' emails.

Furthermore, the aggregated dataset allowed comparative assessment of rural school water quality to:

1. Identify schools with determinands that exceeded $\frac{1}{2}$ MAV and AV thresholds (Water Services [NZDWS] Regulations 2022; Taumata Arowai 2022a).
2. Spatially compare rural drinking-water quality across New Zealand.
3. Provide insights into the current range and maximum values of these determinands for New Zealand's rural water supplies with respect to national standards and guidelines.
4. Provide an overview on school self-reported knowledge of its drinking-water sources, confidence in managing water supplies, ability to interpret drinking-water test reports, and perceived threats to and resilience of its water supplies.

2.5.1 Statistical Methods

For all 29 determinands measured in this study, a description of the mean and standard deviation, median, minimum and maximum values for drinking-water source type is listed in Appendix 4. The median value is preferentially used as a measure of the central tendency of the dataset instead of the mean value, as it is not adversely affected by the existence of extreme outliers or results below the LOD.

When an element's concentration was below the instrument's detection limit, a value equal to half the determinand's LOD was used, for example, fluoride has a LOD of 0.05 mg/L, so the value used for calculations was 0.025 mg/L.

Partial Least Squares Discriminant Analysis (PLS-DA) modelling of determinands and water-source type was conducted using SIMCA-p software (ver. 13.0). PLS-DA provides a multi-variate dimensionality-reduction tool of determinands based on supervised classification of the water-source type. This data reduction method preserves covariance between data and sources and plots the water-source type spatially, surrounded by determinands. The partial least-squares distance between the water source type centroids and each determinand informs the influence of each determinand on the water source type.

2.5.2 Graphical Plots

A distribution histogram and a box and whisker plot are presented for each determinand as a data visualisation tool. The distribution histogram divides each determinand into bins based on concentration and shows the number of schools that group into each bin. Each bin is coloured (green, yellow or red) according to whether the bin is below $\frac{1}{2}$ MAV or AV, between $\frac{1}{2}$ MAV and MAV or above MAV or AV, respectively.

The box and whisker plot divides the ordered values for each water source type into equal 25th and 75th percentiles and is the inter-quartile range (grey-filled box), containing approximately 50% of the data. The whiskers of the plot represent the 5th and 95th percentile range. The median is represented by a vertical line in the middle of the box. Outliers (circles) are defined as being >1.5 times the inter-quartile range, respectively, measured from either the 25th or 75th percentile.

Soft Independent Modelling of Class Analogy (SIMCA) is a classification method based on disjointed Primary Component Analysis modelling. The supervised pattern recognition PLS-DA method was employed for determinand classification analysis using SIMCA-p software (ver. 13.0; Umetrics, Sweden).

2.5.3 Drinking-Water Determinand Maps

The data for each determinand are presented in a geographical map identifying locations or regions of higher determinand occurrence. These maps depict the school sampling locations and their results based on whether the value is below $\frac{1}{2}$ MAV or AV, between $\frac{1}{2}$ MAV and MAV or above MAV or AV. Where there is no set drinking-water regulatory standard, values are plotted according to whether the determinand is within or outside the typical drinking-water range (outlined in Section 3).

All 245 individual reports issued to rural schools and data files were made available to the Ministry for the Environment and the Ministry of Education.

3.0 DETERMINAND SELECTION, SOURCE AND IMPACT DESCRIPTIONS

A suite of determinands was jointly selected during the co-design phase to represent common chemical and aesthetic attributes routinely tested in drinking water (e.g. *E. coli*, turbidity, nitrate, hardness) and investigate determinands that are not routinely determined during monthly rural school drinking-water testing (e.g. arsenic, mercury, fluoride, copper, zinc, boron, etc.) (see Appendix 4 for details).

Two sets of guideline values were used to assess the results:

- NZDWS MAVs describe a specified limit for substances that may cause potential harmful health effects with prolonged exposure (Water Services [NZDWS] Regulations 2022). Determinands to which a MAV applies are indicated by the '#' symbol in sub-headings below.
- AVs specify or provide minimum or maximum values for aesthetic attributes, such as taste and odour, or where there is a risk of staining or residual formations. AVs do not present as a human health concern (Taumata Arowai 2022a). AVs were formerly known as Guideline Values (Ministry of Health 2018). Determinands to which an AV applies are indicated by the '*' symbol in sub-headings below.

Health-significant chemical determinands and aesthetic changes in drinking water can be caused by natural sources, as well as by human activities (Ministry of Health 2017). A brief description outlining the source and impact for each of the 29 determinands selected for this study is provided here.

3.1 Alkalinity

The alkalinity of drinking water refers to its capacity to neutralise acids. It is an important parameter in determining water quality and can have implications for taste, water-scale on glass, water-pipe clogging due to mineral deposition and corrosion in pipes, as well as an environmental impact. Alkalinity is primarily influenced by the presence of bicarbonate, carbonate and hydroxide ions in the water and provides information as to the extent of rock/water interaction. Higher-alkalinity water is more likely to be sourced from limestone aquifers or gravels influenced by carbonate minerals from underlying sediments. Generally, water with higher alkalinity tends to have a higher pH, meaning that it is more basic or alkaline.

Alkalinity is typically measured in milligrams per litre (mg/L) of calcium carbonate (CaCO₃). There are no alkalinity standards for drinking water in New Zealand. The typical alkalinity range for drinking water is from 30 to 400 mg/L as CaCO₃, but there are no specific limits of concern (Kozisek 2020).

Low-alkalinity water can be corrosive, while high-alkalinity water can taste bitter or soapy. However, moderate alkalinity is usually desirable for drinking water, as it provides a buffering capacity against pH changes, which can help stabilise the water's pH and prevent drastic fluctuations.

3.2 Ammonia*

Ammonia in drinking water can originate from various sources, such as agricultural runoff, wastewater discharges, industrial processes and natural decay of organic matter. It is a compound composed of nitrogen and hydrogen (NH₃) and can exist in both its un-ionised form (NH₃) and ionised form (NH₄⁺). In small amounts, ammonia in drinking water is generally

not harmful to health. Ammonia can affect taste and have an unpleasant odour at elevated concentrations above 1.5 mg/L. Potential health risks could arise, as higher levels of ammonia can challenge chlorination efficiency and reduce its effect.

The presence of ammonia in drinking water can indicate contamination and may be associated with pollutants such as fertilisers and animal wastes, or pathogens. Regulatory agencies set standards for acceptable levels of ammonia in drinking water to ensure its safety for consumption. The NZDWS MAV threshold for ammonia concentration is 1.5 mg/L.

Water-treatment processes such as chlorination or chloramination are commonly used to remove or reduce ammonia levels in drinking water.

3.3 Antimony[#]

Antimony is a naturally occurring metalloid element that can be found in the Earth's crust. It may enter drinking-water sources through natural processes, such as erosion of antimony-containing minerals, or through human activities such as mining, industrial discharge or the use of antimony-containing plumbing materials, such as pipes or solder.

Antimony toxicity can lead to gastrointestinal issues, skin irritation, lung problems and potentially more severe health effects with prolonged exposure. The NZDWS MAV for antimony concentration is 0.02 mg/L.

Water-treatment processes such as coagulation, filtration and ion exchange can be effective in reducing antimony levels in drinking water. Regular monitoring and testing of drinking water sources for antimony is recommended for sites that record its presence.

3.4 Arsenic[#]

Arsenic in drinking water is a significant concern due to its potential health effects. Arsenic is a naturally occurring element found in rocks and soil, but also occurs as a result of chemical use in older sheep dips; as part of copper, chrome and arsenic wood treatments; and naturally from geothermal sources. Arsenic may be naturally present at high levels in groundwater and vary with seasonal rainfall effects, especially in shallow bores (Frost et al. 1993). Arsenic is mostly mobile in low-oxygen environments, which occur naturally in New Zealand aquifers. It is tasteless, odourless and colourless, making it difficult to detect without testing.

Long-term exposure to high levels of arsenic in drinking water is associated with various health problems, including skin lesions, cardiovascular disease, respiratory issues and an increased risk of certain types of cancer, such as skin, bladder and lung cancer. Even low levels of arsenic exposure over an extended period can have adverse health effects. The NZDWS MAV for arsenic concentration is 0.01 mg/L.

Water-treatment technologies such as coagulation/filtration, ion exchange, activated alumina and reverse osmosis can effectively reduce arsenic levels in drinking water. Regular monitoring and testing of drinking-water sources for arsenic contamination is recommended for sites that record its presence.

3.5 Boron[#]

Boron is a naturally occurring element that can be found in soil, water and food. It is not typically considered harmful in small amounts and is even considered an essential nutrient for plants, as well as potentially for humans in very low doses. Boron has been detected in some bores that are linked to geothermal sources and may also be associated with arsenic.

Excessive boron intake can lead to health issues, such as gastrointestinal irritation, skin rash and even reproductive problems in high doses. Long-term exposure to high levels of boron can potentially cause more serious health effects. Therefore, it is essential to monitor boron levels in drinking-water sources if its presence is detected to ensure that concentrations remain within safe limits. The NZDWS MAV for boron concentration is 2.4 mg/L.

3.6 Cadmium[#]

Cadmium in drinking water is a concern because it is a toxic heavy metal that can have serious health effects on humans. Cadmium can enter water sources through various routes, including industrial discharges, agricultural runoff and erosion of natural deposits.

Long-term exposure to cadmium in drinking water can lead to kidney damage, anaemia and bone mineral density loss and can potentially increase the risk of cancer. The NZDWS MAV for cadmium concentration is 0.004 mg/L.

Cadmium can be removed using filtration systems that are certified to remove heavy metals. Typically, cadmium is found as an impurity in zinc-galvanised pipes. It may also be present in higher concentrations in waters with lower pH, causing plumbing corrosion.

3.7 Calcium

Calcium is a major ion associated with rock/water interactions from underlying calcareous rocks such as limestones or marble. The presence of calcium in drinking water depends on the geological composition of the area where the water is sourced. Water that flows through limestone and other calcium-rich rocks tends to have higher levels of calcium.

Calcium in drinking water is generally considered beneficial for health, as it is an essential mineral that plays a crucial role in various bodily functions. Calcium is important for maintaining strong bones and teeth, as well as for muscle function, nerve signalling and blood clotting. In areas where the calcium content in drinking water is particularly high, it can contribute to water hardness, leading to problems such as scale deposits forming on hot surfaces (jugs), glass etching (showers) and difficult-to-lather soaps (washing). The sum of calcium and magnesium concentrations is used to calculate water hardness. Hard water, which contains elevated levels of calcium and magnesium ions, may lead to scale build-up in pipes and appliances. While hard water is generally safe to drink, some people may prefer to use water softeners to reduce the hardness for aesthetic reasons or to prolong the life of plumbing fixtures.

Overall, calcium in drinking water is not typically a cause for concern and can contribute to meeting the body's daily calcium requirements. However, as with any mineral in water, excessive intake should be avoided. Typical drinking-water range is 0–80 mg/L as CaCO₃, but there are no specific limits of concern (World Health Organisation 2009).

3.8 Chloride*

Chloride is one of many chemical compounds found in drinking water. It is a naturally occurring mineral and an essential electrolyte for maintaining proper fluid balance in the body. High levels of chloride in drinking water can be indicative of salt-water intrusion into coastal bores or can sometimes indicate groundwater contamination from sources such as road salts, industrial waste or agricultural runoff.

In terms of water quality, chloride levels should be monitored to ensure that they remain within safe limits for human consumption, which can affect taste and corrosion problems and pose health risks if consumed in excess. The AV for chloride concentrations is 250 mg/L.

Treatment methods to reduce elevated chloride concentrations include reverse osmosis or distillation. As treatment is expensive, the preferred approach for high-chloride waters is to identify an alternative water source.

3.9 Chromium#

Chromium is derived from natural geological sources and industrial treatments and exists in several different forms in drinking water. The two most common forms are trivalent chromium (chromium-3) and hexavalent chromium (chromium-6).

Trivalent chromium is an essential nutrient in small amounts and is generally considered safe for human consumption. Conversely, hexavalent chromium is a more toxic form of chromium and can pose health risks if present in drinking water at elevated levels. Prolonged exposure to high levels of hexavalent chromium has been associated with an increased risk of certain health problems, including cancer. The NZDWS MAV for chromium concentration is 0.05 mg/L.

If levels of chromium exceed regulatory limits, water treatment methods such as ion exchange, reverse osmosis or activated carbon filtration may be employed to reduce its concentration to safe levels. Regular testing and monitoring of chromium levels in drinking water are crucial to ensure that it meets safety standards and poses no health risks to consumers.

3.10 Conductivity

Conductivity in drinking water refers to its ability to conduct an electrical current. This property is influenced by the concentration of dissolved ions, such as salts, minerals and other dissolved solids, in the water. Pure water itself is a poor conductor of electricity, but as salts and other ions dissolve in it, conductivity increases. Higher conductivity levels may suggest a greater concentration of dissolved substances, although it does not specifically indicate which substances are present. In general, high levels of conductivity may indicate water/rock interaction due to long residence time, saltwater intrusion, industrial pollutants or agricultural runoff. It is important to note that conductivity alone does not necessarily indicate whether water is safe to drink. Other factors, such as the specific composition of dissolved substances and their concentrations, also need to be considered.

In the context of drinking-water quality, conductivity measurements are often used as an indicator of the water's overall purity or the level of dissolved solids present. It is also useful as an ion balance check and complements other testing parameter estimations, such as Total Dissolved Solids. Regulatory agencies often establish guidelines for acceptable levels of conductivity in drinking water, although no such levels are specified in New Zealand. Typical conductivity of New Zealand drinking water ranges from 0 to 1500 $\mu\text{S}/\text{cm}$, although values below 150 $\mu\text{S}/\text{cm}$ are considered more typical of fresh groundwater (LAWA 2023).

3.11 Copper[#]

Copper is a metal that can be found naturally in the environment.

Copper is an essential nutrient needed by the body in trace amounts, although excessive levels of copper in drinking water can pose health risks such as gastrointestinal discomfort, liver or kidney damage and, in extreme cases, anaemia. High levels of copper in drinking water can cause blue/green staining in water due to various factors, including corrosion of copper pipes or plumbing systems, acidic water conditions or contamination from industrial sources. The NZDWS MAV for copper concentration is 2.0 mg/L.

If copper levels exceed recommended limits, actions such as corrosion control measures, treatment with pH adjustment or installation of alternative plumbing materials may be necessary to mitigate the issue and ensure the safety of drinking water.

3.12 *Escherichia coli*[#]

Although a wide range of pathogens and viruses exist in groundwater, and may cause waterborne illnesses, the presence or absence of micro-organisms in drinking water is usually measured in terms of bacterial species *Escherichia coli* (*E. coli*). It is usually found in human or animal faecal matter and should not be present in drinking water. Contamination may occur where the well bore head is not secure and contaminated surface water can infiltrate the bore, or due to various factors such as inadequate treatment, sewage overflows or runoff from agricultural or animal waste.

While most strains of *E. coli* are harmless, certain strains can cause illness, particularly if they contaminate drinking water. The presence of *E. coli* in source water indicates that the water has been contaminated with faecal matter and may therefore contain other pathogens that can cause illness such as viruses, which are more difficult to test for. While many schools already test their treated water monthly for *E. coli* (along with Total Coliforms), testing for *E. coli* in the tap-water samples was included as an independent check of the effectiveness of the existing water-treatment plant. The NZDWS MAV for *E. coli* is less than 1 count per 100 mL in any sample, indicating that there should be no detectable *E. coli* in treated drinking water and immediate action is necessary to address any contamination.

Measures such as a secure wellhead, UV light disinfection, chlorination, flushing of distribution systems and source-water protection may be implemented to eliminate *E. coli* and prevent future contamination events.

3.13 Fluoride[#]

Fluoride is a mineral that occurs naturally in many water sources, including rivers, lakes, groundwater and in some geothermally influenced waters. It is also commonly added to drinking-water supplies in many communities as a public health measure to help prevent tooth decay and promote dental health.

Fluoride works by strengthening tooth enamel, making it more resistant to acid erosion and decay. However, excessive intake of fluoride can lead to dental fluorosis (mottling or discoloration of teeth) and, in severe cases, skeletal fluorosis (a condition affecting bones and joints). The optimal level of fluoride in drinking water for dental health is typically in the range of 0.7 to 1.2 mg/L, and the NZDWS MAV for fluoride concentration is 1.5 mg/L.

3.14 Free Carbon Dioxide

Free carbon dioxide (CO₂) in drinking water refers to the dissolved gaseous form of carbon dioxide that is not involved in the formation of bicarbonate (HCO₃⁻) or carbonate (CO₃²⁻) ions. It is a naturally occurring component of water and plays various roles in water chemistry and taste. When water encounters the atmosphere, it can absorb carbon dioxide, forming carbonic acid (H₂CO₃). This process is known as carbonation and is responsible for the slightly acidic taste often associated with carbonated beverages. The amount of free CO₂ can also indicate the extent of rock/water interaction and is usually higher when there is little dissolved oxygen in the water.

In drinking water, free carbon dioxide can affect taste and pH. It can give water a slightly acidic or refreshing taste, similar to carbonated water, especially in natural spring-water sources, where it may be present in higher concentrations. From a water-quality perspective, free carbon dioxide is generally considered harmless at typical concentrations found in drinking water, with a typical range from 0 to 50 mg/L at 25°C. However, high levels of carbon dioxide can lower the pH of water, making it more acidic, which may affect the taste and potentially corrode copper tubing and other metal plumbing systems if not properly managed.

Water-treatment processes such as aeration, filtration and chemical treatment can be employed to control carbon dioxide levels and adjust pH to ensure that water quality and taste meet regulatory standards and consumer preferences.

3.15 Hardness*

Hardness in drinking water refers to the concentration of dissolved minerals, primarily calcium and magnesium ions, and is defined as the sum of calcium and magnesium concentrations. Water hardness is typically measured in terms of mg/L or parts per million (ppm) of calcium carbonate (CaCO₃) equivalents.

Elevated hardness can lead to various issues mentioned above and affect the efficiency of domestic water-treatment processes, necessitating treatment to improve water quality and usability. The hardness level of water can vary widely depending on the source, with soft water having low concentrations of calcium and magnesium ions (typically below 60 mg/L) and hard water having higher concentrations (above 120 mg/L). The AV for hardness in water is 200 mg/L.

Water hardness is typically classified into two types:

- **Temporary hardness:** This type of hardness is primarily caused by the presence of bicarbonate minerals, mainly calcium bicarbonate [Ca(HCO₃)₂] and magnesium bicarbonate [Mg(HCO₃)₂]. Temporary hardness can be removed or reduced by boiling the water, which causes the bicarbonate minerals to decompose and precipitate out as insoluble carbonate minerals. This hardness is called 'temporary' because it can be removed through simple processes such as boiling or by using lime-softening methods.
- **Permanent hardness:** This type of hardness is caused by the presence of sulphate, chloride and nitrate salts of calcium and magnesium. Permanent hardness cannot be removed by boiling because it is not due to the presence of bicarbonates. Instead, it requires more complex treatment methods, such as ion exchange, lime softening or reverse osmosis to reduce the concentration of calcium and magnesium ions.

Hard water can lead to the build-up of scale deposits in pipes, water heaters and appliances, reducing their efficiency and lifespan. Hard water reacts with soap to form a sticky residue known as soap scum, which can leave spots on dishes, glassware and shower surfaces. Hard water may also interfere with the effectiveness of soaps and shampoos. However, water with low hardness ($<100 \text{ g/m}^3$) may be more corrosive.

High calcium hardness is an issue for water treatment UV disinfection systems and can result in scale formation on the glass sleeves, resulting in less effective disinfection. Pre-treatment to reduce hardness below a level of 200 mg/L is recommended to ensure reliable disinfection.

3.16 Iron*

Iron is a naturally occurring element in groundwater derived from iron leaching from geological or bacterial sources. Iron is mostly mobile in low-oxygen environments, which occur naturally in New Zealand aquifers. It may also be derived from iron pipes or from specific water treatments using iron salts as coagulating agents. Elevated iron may be associated with manganese, and its presence is often localised, so the absence of iron in nearby bores cannot be a reliable indicator. Iron may vary significantly with time and seasonal effects, particularly in shallow unconfined groundwater.

Excessive intake of iron from drinking water can lead to health issues such as gastrointestinal discomfort, particularly for individuals with certain health conditions such as hemochromatosis (a genetic disorder causing excess iron absorption) and gastrointestinal discomfort. Elevated iron concentrations in water can also provide a source of nutrients for certain bacteria, leading to the growth of iron bacteria. While these bacteria are generally harmless to health, they can cause issues such as slime build-up in plumbing systems and foul odours. High levels of iron can cause water to appear discoloured, often giving it a reddish, yellowish or brownish tint. This can stain laundry, plumbing fixtures and appliances, as well as affect the taste and odour of the water. The AV for iron concentration is 0.3 mg/L.

Iron is often associated with organic matter deposits that inhibit treatment processes designed to remove metals from water. Removal of iron from water is undertaken through oxidation from its soluble ferrous (Fe^{2+}) form to its insoluble ferric (Fe^{3+}) form, which can then be filtered out or precipitated. Various filtration methods, such as activated carbon filters, multimedia filters or oxidising filters, can effectively remove iron particles from water. Ion exchange water softeners can also remove iron, along with other minerals, particularly in the form of ferrous iron.

3.17 Lead#

Lead is a toxic metal with widespread historical use (e.g. roof flashing, lead-based paint and petrol additive) that has caused extensive environmental contamination and health problems. Lead can enter drinking water through the corrosion of plumbing materials, particularly in older homes where lead pipes or lead solder were commonly used.

Even at low levels, lead exposure can have serious health effects, especially in children, causing developmental delays, learning disabilities and behavioural problems. In adults, lead exposure can lead to cardiovascular issues, kidney problems and reproductive harm. The NZDWS MAV for lead concentration is 0.01 mg/L.

The use of certified filters can remove or significantly reduce lead. If water has been sitting in lead plumbing for several hours, such as overnight, flush the cold water tap for at least two minutes before using it for drinking or cooking to reduce the risk of lead exposure. Use only cold water for cooking and drinking to minimise lead leaching from plumbing materials.

3.18 Magnesium

Magnesium is a major ion associated with rock/water interactions from underlying calcareous rocks, such as limestones or marble. The concentration of magnesium in drinking water can vary depending on factors such as the geological composition of the area and the source of the water. In general, groundwater sources tend to have higher levels of magnesium compared to surface-water sources.

Drinking water with adequate levels of magnesium can contribute to overall magnesium intake and potentially provide health benefits. Some research suggests that magnesium-rich water may have positive effects on cardiovascular health, bone density and muscle function. However, it is important to note that the amount of magnesium consumed through drinking water is typically relatively low compared to other dietary sources such as nuts, seeds, whole grains and leafy green vegetables. At higher levels, magnesium may cause gastrointestinal discomfort in some individuals or have a laxative effect. Higher magnesium concentrations may also lead to increased water hardness, leading to problems such as scale deposits forming on hot surfaces (jugs), glass etching (showers) and difficult-to-lather soaps (washing). Additionally, water with very high magnesium concentrations may have a bitter taste or leave a residue on surfaces. The typical MgCO_3 concentration range for drinking water is from 0 to 100 mg/L, but there are no specific limits of concern (World Health Organisation 2009).

3.19 Manganese[#] *

Manganese is another naturally occurring mineral that can be found in varying concentrations in drinking-water sources depending on factors such as geological conditions and the source of the water, as well as human activities such as mining and industrial processes. Manganese is mostly mobile in low-oxygen environments, which occur naturally in New Zealand aquifers. Groundwater sources may have higher levels of manganese compared to surface-water sources.

Like magnesium, manganese is an essential nutrient for human health, playing a role in various biological processes such as metabolism, bone formation and anti-oxidant activity. Long-term exposure to high levels of manganese in drinking water has been associated with neurological effects, including cognitive deficits and behavioural changes, particularly in children. Moreover, manganese has some aesthetic concerns in water. It naturally dissolves into groundwater under anoxic conditions (low oxygen and pH), which are commonly found for shallow groundwater due to microbial activity and removal of oxygen from the water. The bacteria respire carbon dioxide, raising the free carbon dioxide levels of the water, which dissolves to form carbonic acid and subsequently lowers the pH of the water. The AV for manganese concentration is 0.04 mg/L for staining of laundry and plumbing fixtures and 0.10 mg/L for taste. The NZDWS MAV for manganese is 0.4 mg/L.

Treatment processes such as filtration or ion exchange can be used to reduce manganese concentrations if it exceeds regulatory limits.

3.20 Mercury[#]

Mercury is a toxic heavy metal that can contaminate drinking-water sources through natural processes such as geothermal springs and erosion of rocks and soil, as well as human activities such as industrial discharge and mining. Mercury exists in different forms, including elemental mercury, inorganic mercury compounds and organic mercury compounds such as methylmercury, which is particularly concerning due to its bio-accumulative nature. The origin

of mercury can be from multiple sources: volcanic activities; emissions; industrial equipment such as thermometers, mercury cells, electrodes, etc.; and homeopathic remedies. Mercury has been noted in detectable levels in soils associated with schools due to historical disposal of mercury-based mixes through burning of dental-clinic wastes in incinerators, treated wood chips used in playgrounds and burning of coal (Turnbull et al. 2019).

Mercury toxicity can have serious health effects, particularly on the nervous system, kidneys and cardiovascular system. In pregnant women, exposure to high levels of methylmercury can harm foetal development and lead to neurodevelopmental issues in the unborn child. The NZDWS for mercury concentration is 0.007 mg/L.

Treatment processes such as filtration, ion exchange or chemical treatment are used to reduce mercury concentrations.

3.21 Nitrate-N[#]

Nitrate is a compound composed of nitrogen and oxygen that naturally occurs in soil, water and air. It is also a common component of fertilisers used in agriculture and arises from animal urine and waste. Nitrate can enter drinking-water sources through various pathways, including runoff from agricultural fields, subsequent leaching of animal wastes into the soil and groundwater, discharge from wastewater treatment plants and septic system leakage. Nitrate contamination of groundwater has become a pressing problem facing rural New Zealand (Rogers et al. 2023), with key farming regions such as Waikato, Taranaki, Horizons, Canterbury and Southland prone to higher levels of nitrates in drinking water. Nitrates are elevated in regions where land-use activities increase the rate of leaching losses from soil or where there are large discharges of polluted water to land.

While low levels of nitrate in drinking water are generally not harmful, elevated levels can pose health risks, particularly for bottle-fed infants and pregnant women. In the body, nitrate can be converted into nitrite, which can interfere with the blood's ability to carry oxygen, leading to a condition called methemoglobinemia, or 'blue baby syndrome', in infants. Additionally, long-term exposure to high levels of nitrate in drinking water has been associated with other health issues, such as increased risk of certain cancers and adverse reproductive outcomes. The current NZDWS MAV for nitrate is 11.3 mg/L as nitrate-N. As aforementioned, a growing body of evidence is currently being developed to review this standard (see Section 1.0).

Treatment processes such as ion exchange, reverse osmosis or biological denitrification can reduce nitrate concentrations if these exceed regulatory limits. Private drinking-water wells should be routinely tested for nitrates, especially in rural regions prone to high nitrate levels in groundwater.

3.22 Nitrite-N[#]

Nitrite is a compound composed of nitrogen and oxygen, closely related to nitrate. Like nitrate, nitrite can enter drinking-water sources through various pathways, including agricultural runoff, animal wastes, wastewater discharge and septic-system leakage. Nitrite can also form in water because of the biological decomposition of organic matter.

In drinking water, nitrite is of concern primarily due to its potential health effects, particularly when it is converted to nitrosamines, which are known carcinogens, in the body. Additionally, high levels of nitrite in drinking water can interfere with the blood's ability to carry oxygen, leading to methemoglobinemia, or 'blue baby syndrome', particularly in infants. The NZDWS MAV for nitrite is 0.91 mg/L as NO₂-N for short-term exposure and 0.2 mg/L for long-term exposure.

Treatment processes such as ion exchange, reverse osmosis or biological denitrification may be used to reduce nitrite concentrations. Additionally, it is recommended that private wells used for drinking-water purposes should be regularly tested for nitrites and nitrates to ensure water safety.

3.23 pH*

The pH of drinking water refers to its level of acidity or alkalinity, determined by the concentration of hydrogen ions in the water. The pH scale ranges from 0 to 14, with 7 being neutral. Values below 7 indicate acidity, while values above 7 indicate alkalinity. The pH of drinking water can vary depending on factors such as the source of the water, the geological characteristics of the area and any treatment processes that the water may undergo. Generally, groundwater sources tend to have a slightly acidic to neutral pH, while surface-water sources such as rivers and lakes may have a wider range of pH values influenced by factors such as organic matter and dissolved minerals.

Low pH levels (<6.5) can indicate poorly purged pipes and may cause water to have a sour or metallic taste. Water with a pH close to neutral (around 7) typically has a more pleasant taste and odour compared to water with extreme pH values. Water that is too acidic (<6.5) or too alkaline can corrode plumbing materials, potentially leading to issues such as metal leaching into the water or damage to pipes and fixtures. This may lead to higher levels of dissolved metals, such as copper, iron, lead or zinc. The effectiveness of water-treatment processes, such as disinfection with chlorine or chloramine, can be influenced by pH. Maintaining a proper pH level ensures that treatment processes work as intended to remove contaminants and ensure water safety. The AV for pH is set as a range from 7.0 to 8.5.

Chlorine disinfection may not be as efficient at lower pH, and UV treatment is preferred.

3.24 Potassium

Potassium is a naturally occurring mineral that can be found in varying concentrations in drinking-water sources. The concentration of potassium in drinking water can vary depending on factors such as the geological composition of the area and the source of the water. Groundwater sources may have higher levels of potassium compared to surface water sources, as potassium can also be indicative of old marine deposits.

Potassium is an essential nutrient for human health, playing a crucial role in various bodily functions such as muscle and nerve function, fluid balance and heart rhythm regulation. Potassium-rich water may be especially beneficial for individuals who do not consume enough potassium through their diet, as it can help maintain healthy blood-pressure levels and reduce the risk of cardiovascular disease. While potassium is generally considered safe to consume in drinking water, excessively high levels of potassium in water are rare and may be associated with health risks, particularly for individuals with certain medical conditions, such as kidney disease or those taking medications that affect potassium levels. Higher potassium levels may also adversely affect the aesthetic properties of water. The typical potassium concentration range in drinking water is from 0 to 8 mg/L (World Health Organisation 2009).

3.25 Sodium*

Sodium can be indicative of salt-water intrusion into coastal bores or can arise from the weathering of rocks and soil, as well as through human activities such as road salt application, wastewater discharge and industrial processes.

While sodium is an essential nutrient for the body and is necessary for various physiological functions, excessive intake of sodium can have negative health effects, particularly on blood pressure and cardiovascular health. The contribution of sodium from drinking water to total sodium intake is relatively small compared to dietary sources such as salt (sodium chloride) added to food. However, in areas where drinking-water sources have elevated sodium levels, drinking water can contribute significantly to sodium intake, particularly for individuals who rely heavily on tap water for hydration. The AV for sodium concentration is 200 mg/L.

3.26 Sulphate*

Sulphate occurs naturally in the environment from the weathering of rocks and minerals containing sulphur compounds. Sulphate can also enter water sources through human activities such as industrial processes, mining operations and wastewater discharge.

In general, sulphate levels in drinking water are not typically harmful to human health at concentrations found in most water sources. However, in some cases, elevated levels of sulphate in drinking water can lead to aesthetic issues such as a bitter taste, odour or a laxative effect, particularly in individuals who are sensitive to high sulphate concentrations. The primary concern with sulphate in drinking water is its potential to react with organic matter and certain metals to form sulphides, which can cause corrosion of plumbing materials and infrastructure. This can lead to issues such as metallic taste, discoloration of water and damage to pipes and fixtures. The AV for sulphate concentration is 250 mg/L.

Water treatment processes such as ion exchange, reverse osmosis or activated carbon filtration can be used to reduce sulphate concentrations if they exceed regulatory limits or cause aesthetic issues.

3.27 Total Dissolved Solids*

Total dissolved solids (TDS) refer to the combined content of all inorganic and organic substances dissolved in water. These substances can include minerals, salts, metals, ions and some organic compounds. TDS is typically measured in mg/L. The presence of dissolved solids in drinking water is a natural occurrence and can come from various sources, including geological formations through water/rock interaction, agricultural runoff (fertilisers and pesticides used in agriculture can dissolve in water), urban runoff (road salt and other chemicals used in urban areas), industrial discharge (effluents from industrial processes) and wastewater discharge (treated or untreated wastewater discharged into water bodies). Bores close to the ocean can also have elevated TDS through saltwater intrusion.

While some dissolved solids in drinking water are harmless, and even beneficial (such as essential minerals like calcium and magnesium), excessively high levels of TDS can affect the taste, odour and appearance of water. Additionally, high TDS levels may indicate the presence of other contaminants in water that could pose health risks if consumed in high concentrations. Higher levels may affect water-filtration efficiency. The AV threshold for TDS is 1000 mg/L, and it is also noted that taste may be affected between 600 and 1200 mg/L.

Treatment processes such as filtration, reverse osmosis or distillation can be implemented to reduce TDS concentrations if they exceed recommended levels or cause aesthetic issues.

3.28 Turbidity *

Turbidity in drinking water refers to the cloudiness or haziness of the water caused by suspended particles such as sediment, silt, clay, organic matter and micro-organisms. These particles scatter and absorb light, making the water appear cloudy or murky. Turbidity is typically measured in nephelometric turbidity units (NTU) or formazin nephelometric units (FNU). It is routinely monitored in surface-water samples but not in groundwater, where some natural filtration is expected to occur.

High levels of turbidity in drinking water can have several implications. Water with high turbidity may have an undesirable appearance, taste and odour, which can affect consumer acceptance and satisfaction with the water quality. Turbidity can also serve as a vehicle for pathogens such as bacteria, viruses and protozoa to attach to and be transported in water. While turbidity itself does not necessarily indicate the presence of harmful micro-organisms, high turbidity levels can reduce the efficiency of domestic water treatment (such as chlorination) or filtration processes and clog filters, potentially compromising the safety of drinking water.

Elevated turbidity (measured in NTU) can affect the efficiency of domestic water-treatment filtration processes and clog filters. The AV threshold for turbidity is 5 NTU.

Typically, turbidity levels are monitored in drinking water throughout the treatment and distribution process to ensure compliance with regulatory standards and maintain water quality. Treatment processes such as coagulation, flocculation, sedimentation, filtration and disinfection are employed to reduce turbidity levels and provide safe and clear drinking water to consumers.

3.29 Zinc*

Zinc can naturally enter water sources through processes such as weathering of rocks and soil, as well as through human activities, including industrial discharge, mining operations and corrosion of zinc-containing materials.

In small amounts, zinc is an essential nutrient for human health, playing a role in various biological processes such as immune function, wound healing and DNA synthesis. However, excessive intake of zinc, particularly through drinking water, can have adverse health effects. High levels of zinc in drinking water can lead to gastrointestinal discomfort, such as nausea, vomiting and diarrhoea. Long-term exposure to elevated zinc levels may also affect liver and kidney function. The AV for zinc concentration is 1.5 mg/L.

Treatment processes include corrosion control, filtration, ion exchange or chemical precipitation.

4.0 ENGAGEMENT SURVEY RESULTS

This section summarises the engagement survey questions and responses received from rural schools. It provides a stocktake of school-owned drinking-water supplies, as well as an overview of challenges and limitations that rural schools face when managing these, based on 265 school responses from 288 schools listed in the Ministry of Education's database.

4.1 What is the main source of drinking water for your school?

As the target group for this study, most rural schools (72.5%) identified groundwater as their main source of drinking water, supplied from bores or springs, while rainwater (17.7%) was also used as a primary source, with bore water as a secondary supply (Figure 4.1). Other sources mostly stated that they used rural water schemes.

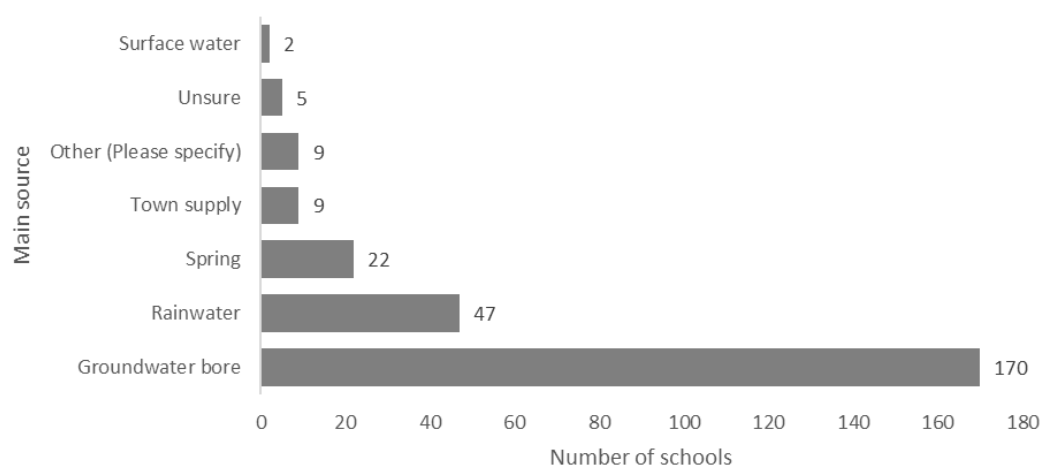


Figure 4.1 Main drinking-water source at surveyed schools.

4.2 What additional sources of drinking water are available, if any?

Around 68.3% of rural schools had only one source of drinking water, while some schools also had a back-up source for their groundwater bore (12.5%) or rainwater tanks (9.8%) (Figure 4.2). Other additional sources covered a range of options. Two schools stated that they have water delivered by tanker to their school. Another four schools either purchased water for staff and/or students, or students are expected to bring a water bottle from home, as there was no potable water onsite due to on-going issues with water supply contamination.

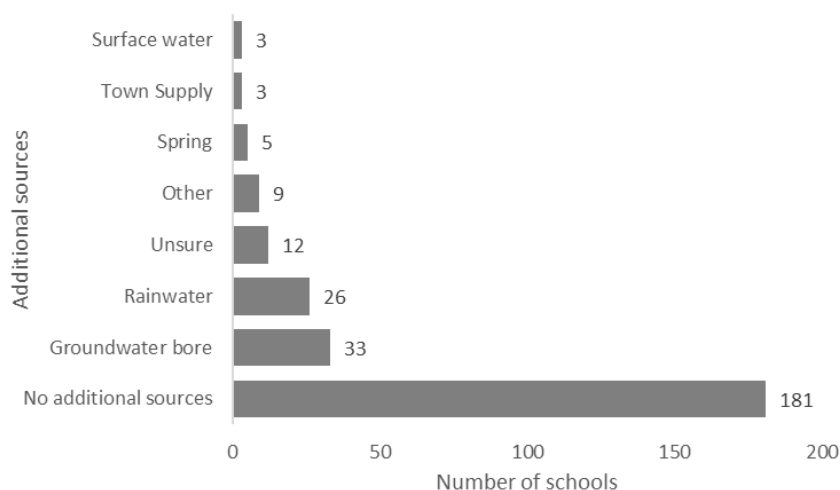


Figure 4.2 Availability of alternative drinking-water supplies of surveyed schools.

4.3 If your school drinking-water supply comes from a groundwater bore or well, what is the bore/well depth in metres?

Bore depth information was only supplied at 43 sites out of 170 bore supplies. Where information was provided, most bores were shallow (<40 m), with only eight bores having a maximum depth greater than 80 m (Figure 4.3). The low number of responses for this question indicates that schools generally do not have information on their bore due to age or lack of records held at the school. Many survey responders were school administration staff who had no knowledge of the bore details.

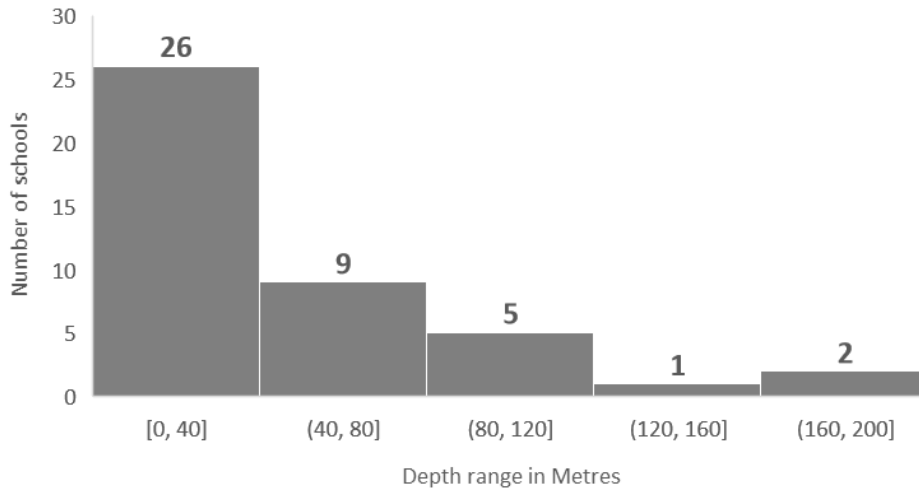


Figure 4.3 Bore depth range of drinking-water supply from the participants. Note that one school reported a bore or well depth exceeding 60,000 m, which is likely to be a unit conversion error in the data capture, i.e. millimetres instead of metres. Due to the uncertainty on the depth, this response was excluded from this figure.

4.4 What is the maximum number of people who may use this water for drinking purposes?

Most rural schools in the study supply drinking water to between 26 and 500 students, with 10 schools servicing more than 500 students (Figure 4.4). Only 20 rural schools reported supplying less than 25 students. Regulatory testing of water supplies is mandatory for supplies serving more than 25 people.

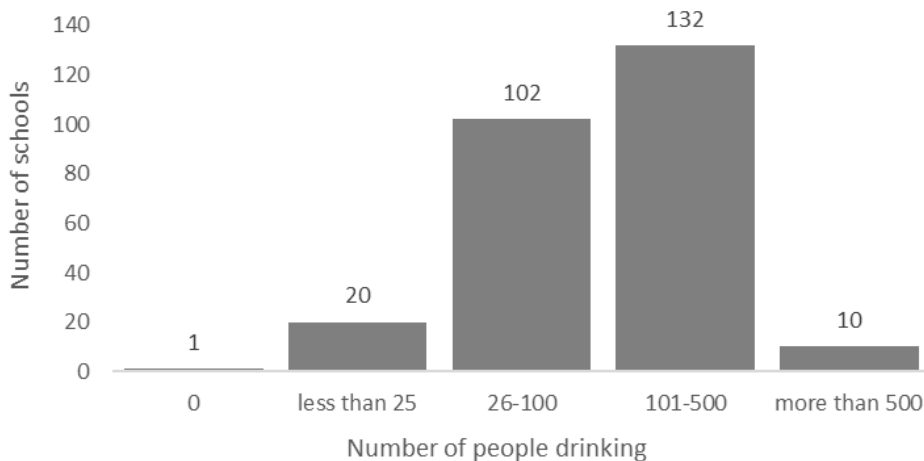


Figure 4.4 Serving size estimation from participants for their drinking-water supply.

4.5 If you are using ground or spring water for your drinking water supply, when was it last tested?

Most rural schools in the study reported that they had undertaken water testing within the last year (76%); however, 21% of schools did not respond to the question and 3% of schools were not monitoring annually, with some tests dating back to 2019 (Table 4.1). Note that the breadth of each analytical suite (e.g. *E. coli* and/or other determinands) was not reported by schools. While the Ministry of Education holds a database of school water testing, some schools do not routinely report their results back to the Ministry, or they only test for *E. coli* and Total Coliforms. This survey provides the first comprehensive groundwater assessment of a large number of rural schools over the same time frame, allowing a national spatial comparison.

Table 4.1 Summary of the dates of the latest drinking-water testing for surveyed schools.

Answer	Count
1 Jun 2019 – 1 Jul 2019	1
1 Oct 2020 – 1 Nov 2020	1
1 Nov 2021 – 1 Dec 2021	1
1 Dec 2021 – 1 Jan 2022	1
1 Sep 2022 – 1 Oct 2022	1
1 Nov 2022 – 1 Dec 2022	3
1 Feb 2023 – 1 Mar 2023	1
1 Jun 2023 – 1 Jul 2023	1
1 Jul 2023 – 1 Aug 2023	1
1 Aug 2023 – 1 Sep 2023	29
1 Sep 2023 – 1 Oct 2023	77
1 Oct 2023 – 1 Nov 2023	48
1 Nov 2023 – 1 Dec 2023	33
1 Jan 2024 – 1 Feb 2024	7
1 Feb 2024 – 1 Mar 2024	4
1 Mar 2024 – 1 Apr 2024	1
No response	55
Total	265

4.6 Do you know which determinands were tested?

Schools were asked if they knew which analyses were tested in their most recent water tests. Of the 265 responding schools, 75% of schools knew which determinands had been tested (Figure 4.5). Around 11% of schools did not know which determinands had been tested, and 14% were unsure. The main reason for the higher rate of uncertain or unknown responses was due to the person responding to the survey. Many of the respondents were administration staff, rather than the principal or caretaker, usually responsible for routine water testing.

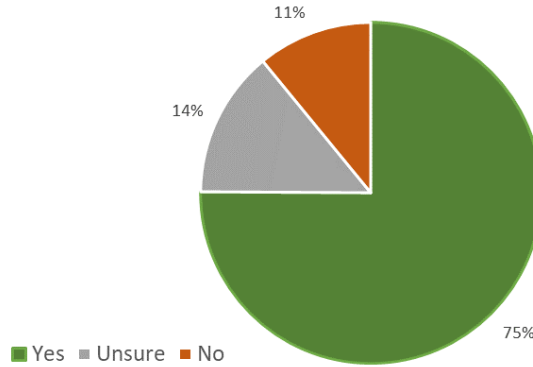


Figure 4.5 Awareness self-assessment of determinands analysed during the latest water testing from participants.

4.7 Which determinands were tested?

The most frequently tested determinand was *E. coli* and Total Coliforms (72.5%), followed by pH (5.3%) and turbidity (4.2%), although 67 schools did not respond to this question (Figure 4.6). These responses suggest that either respondents did not know which determinands are tested routinely, or that most NZDWS determinands are not routinely tested at rural schools in the study, leaving significant gaps and risks for their drinking water security and safety. Until 2021, testing for *E. coli* and Total Coliforms in treated water was the only water testing requirement set by the Ministry of Education for rural self-supplied schools.

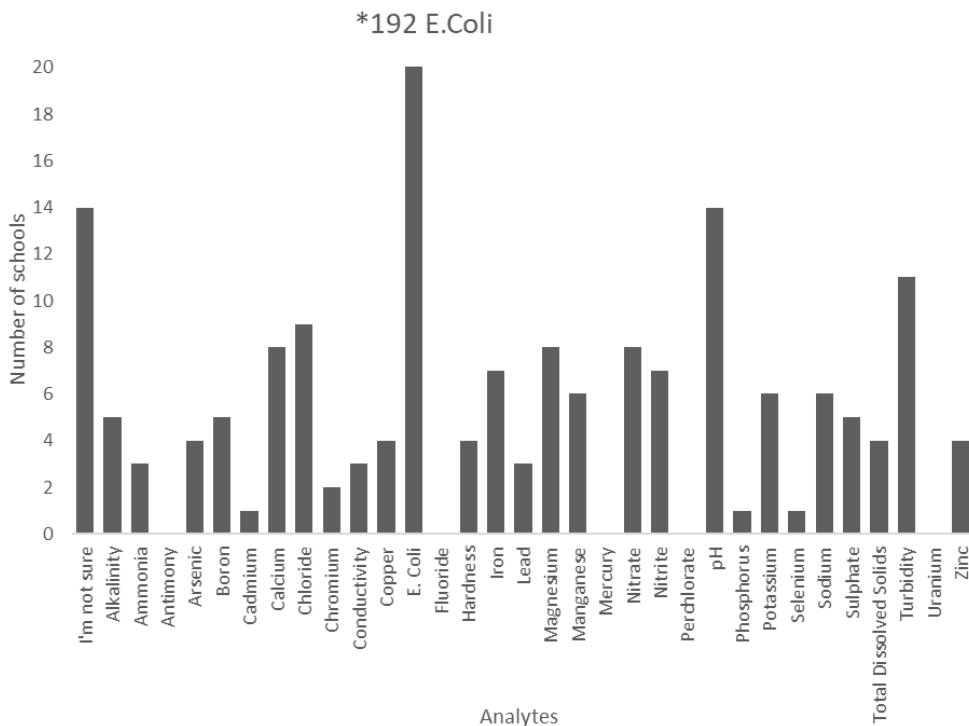


Figure 4.6 Summary of most recently tested determinands according to surveyed schools.

4.8 How confident are you / your school in interpreting drinking-water test reports to understand your water quality?

Around 39.6% of schools felt very confident that they could correctly interpret their laboratory report, while 45.7% of schools felt only somewhat confident (Figure 4.7). Around 9.8% of schools did not feel confident at all and would like to have more support.

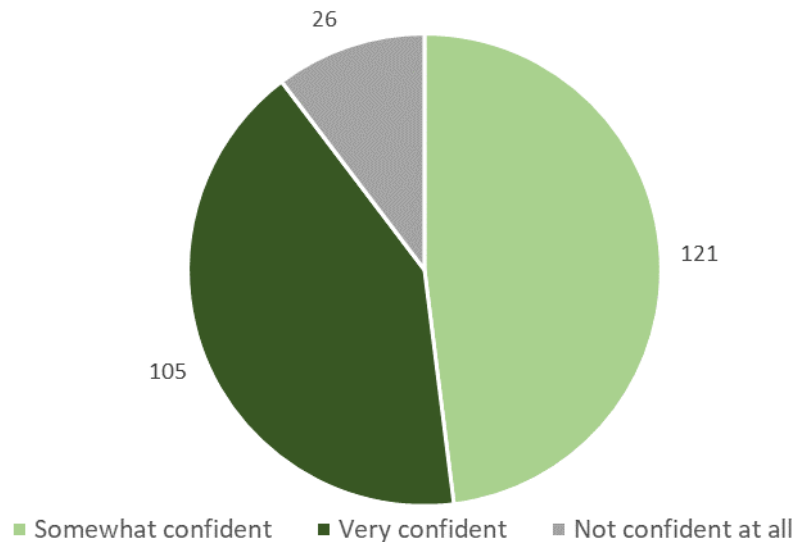


Figure 4.7 Self-assessment of confidence in interpreting water-testing results for the surveyed schools.

4.9 Is your school used as a Civil Defence evacuation centre or do you host large community gatherings from time to time, where people drink the existing water supply?

The highest alternate use of school facilities was for community gatherings (61.9%), then as a Civil Defence Centre in emergencies (30.9%) (Figure 4.8). Only 23.4% of schools did not share their school property with other users, while a small number (4.2%) listed other community events such as pet days, fairs, athletics day, etc., where local residents attend one-off events.

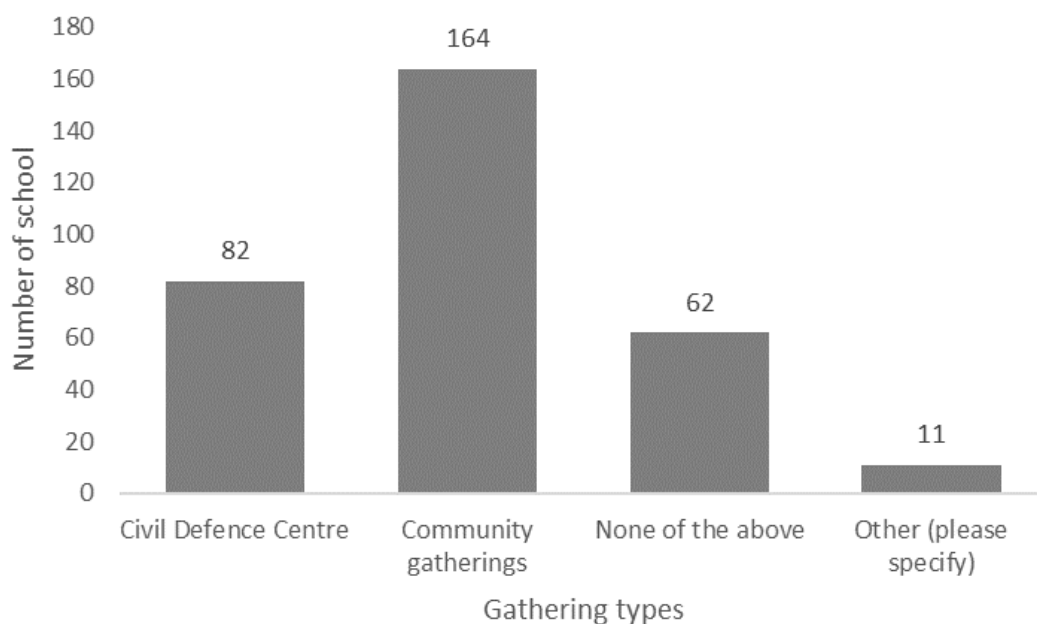


Figure 4.8 Occurrences of external uses of school facilities that may involve the use of drinking water for surveyed schools.

4.12 In order to take part in the national survey, is there someone who can collect water directly from your water source (bore or spring) into sample bottles following clear written instructions?

Around 63.0% of schools felt competent to collect water from their source, while 37.0% of schools did not (Figure 4.11). This was not reflected in the breakdown of the samples received in this survey, which comprised 35% of samples from bores or surface water. Around 65% of samples were collected from staffroom taps or drinking-water fountains, as collecting water from the source would be too time consuming or the responding staff did not feel competent to collect a water sample from the untreated source.

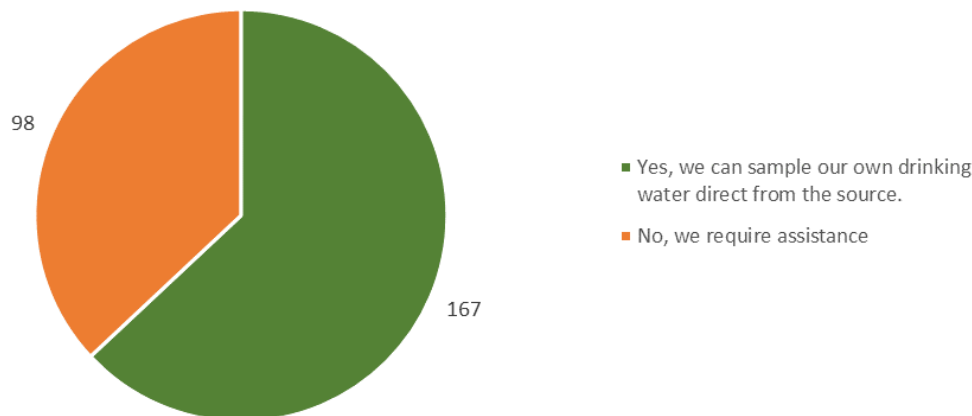


Figure 4.11 Self-assessment of competency to collect water samples for testing from participants.

4.13 Do you have someone capable of managing your school's water supply?

Generally, the principal or caretaker is responsible for day-to-day management of the water supply, including completing water sampling for laboratory testing. In some instances, local water-testing agencies are contracted to undertake monthly sampling. While 70.6% of rural schools felt that they had someone capable of managing their school's water supply, 29.4% of schools felt that they had no-one capable of managing their water supply or were not sure and required more support (Figure 4.12).

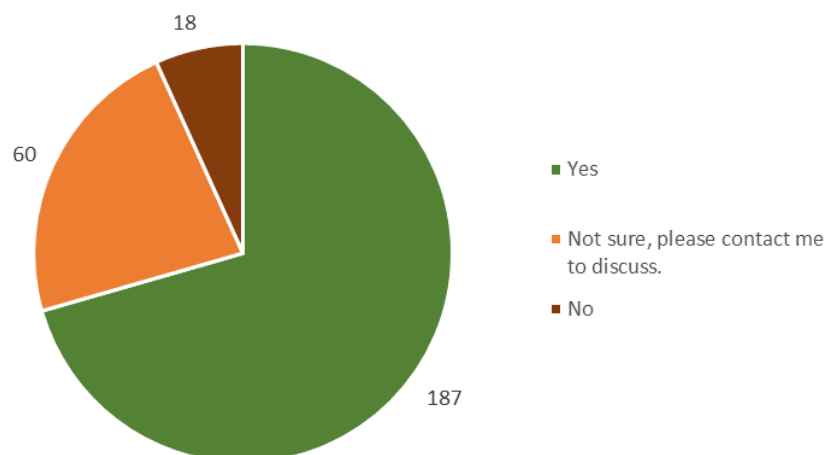


Figure 4.12 Self-assessment of the ability of surveyed rural schools to manage their water supply.

Along with these responses, we also identified significant barriers and challenges for rural schools in respect of taking part in decentralised routine testing, including inadequate time, lack of staff availability or competency to undertake the sampling (see Section 7.0).

5.0 WATER DETERMINAND RESULTS

The following section presents the results for each determinand using a map showing spatial distribution of measured values colour-coded against the NZDWS. A table summarises the sample count, non-detected samples, NZDWS threshold if applicable, statistics on measured values, a histogram depicting the concentration range per water type and boxplots of concentrations by water sample type. The table also includes an indication of the number of people potentially affected by exceedances based on Ministry of Education school roll statistics for 2023 (supplied by the Ministry).

5.1 Classification of Water-Source Type

The study assessed 245 rural schools that were able to provide a water sample for testing (Figure 5.1). The cohort included 182 schools from the North Island, 62 schools from the South Island and a school from Pitt Island. The study requested that schools provide an untreated or 'raw' source-water sample to learn more about regional groundwater quality and its suitability for drinking water. However, the location of the water sample submitted by each school depended on several factors, including the presence of sampling taps at the bore or treatment plant and the ability of the school to sample the untreated bore water or surface-water source. To ensure that no school was left out of the study because of its inability to sample water directly from the source, schools were encouraged to submit a water sample from their staffroom kitchen tap or a drinking-water fountain. Water samples were classified into three main groups:

- **Bore water:** These samples consisted of untreated groundwater, sampled directly from the bore. It was possible that some samples classed in this group were sampled after water treatment, but this was not disclosed. Bore-water samples were assumed to represent the local aquifer source. There were 72 water samples classed as bore water.
- **Surface water:** This group comprised a range of untreated source waters from springs and surface water. There were 14 samples classed as surface water including 12 springs, a river sample and a creek sample. All surface-water samples were assumed to be untreated. It should be noted that, although springs are included in this group, springs are the surface expression of groundwater. This has implication on their flow mechanism, possible lag times and capture zone.
- **Tap water:** There were 159 samples classed as coming from treated tap water. While the eligibility to participate in this study was that the school needed to be using groundwater, tap samples represented the bore water or surface water after water treatment and provided a snapshot of the potable water quality instead of the groundwater quality. For some tap-water samples, groundwater is pumped from the bore into holding tanks and mixed with rainwater. Data supplied by the Ministry of Education suggested that there were 122 schools using tap water sourced only from bore water and a further 22 sites where groundwater and rainwater were mixed. Nine tap water samples were from springs after treatment processes, and two further samples were treated water from surface-water sources. There were also four schools in this study that used town supply for some of their drinking water.

Sample Source Type

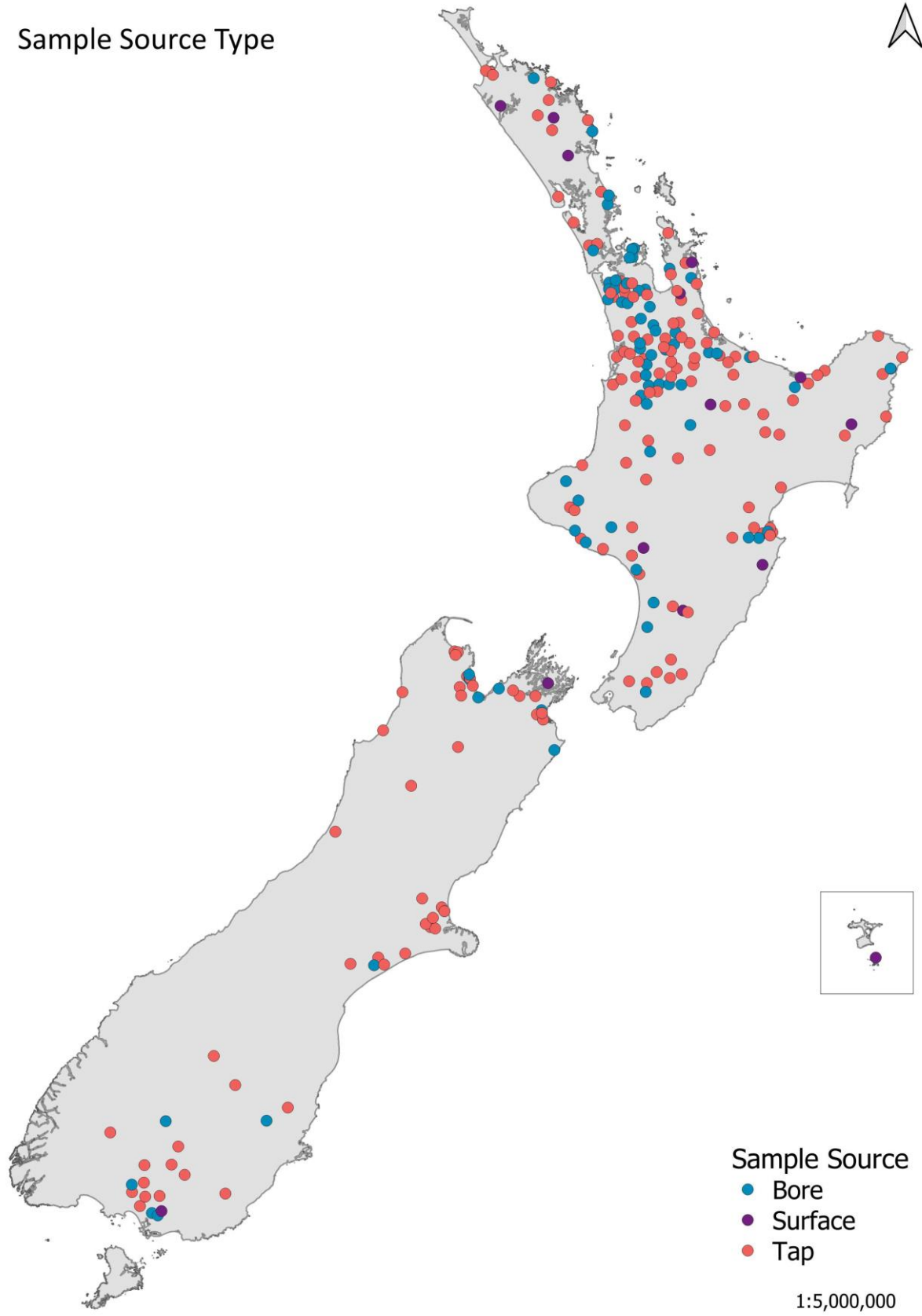


Figure 5.1 Spatial distribution of sampled schools by water-source type.

5.2 Alkalinity

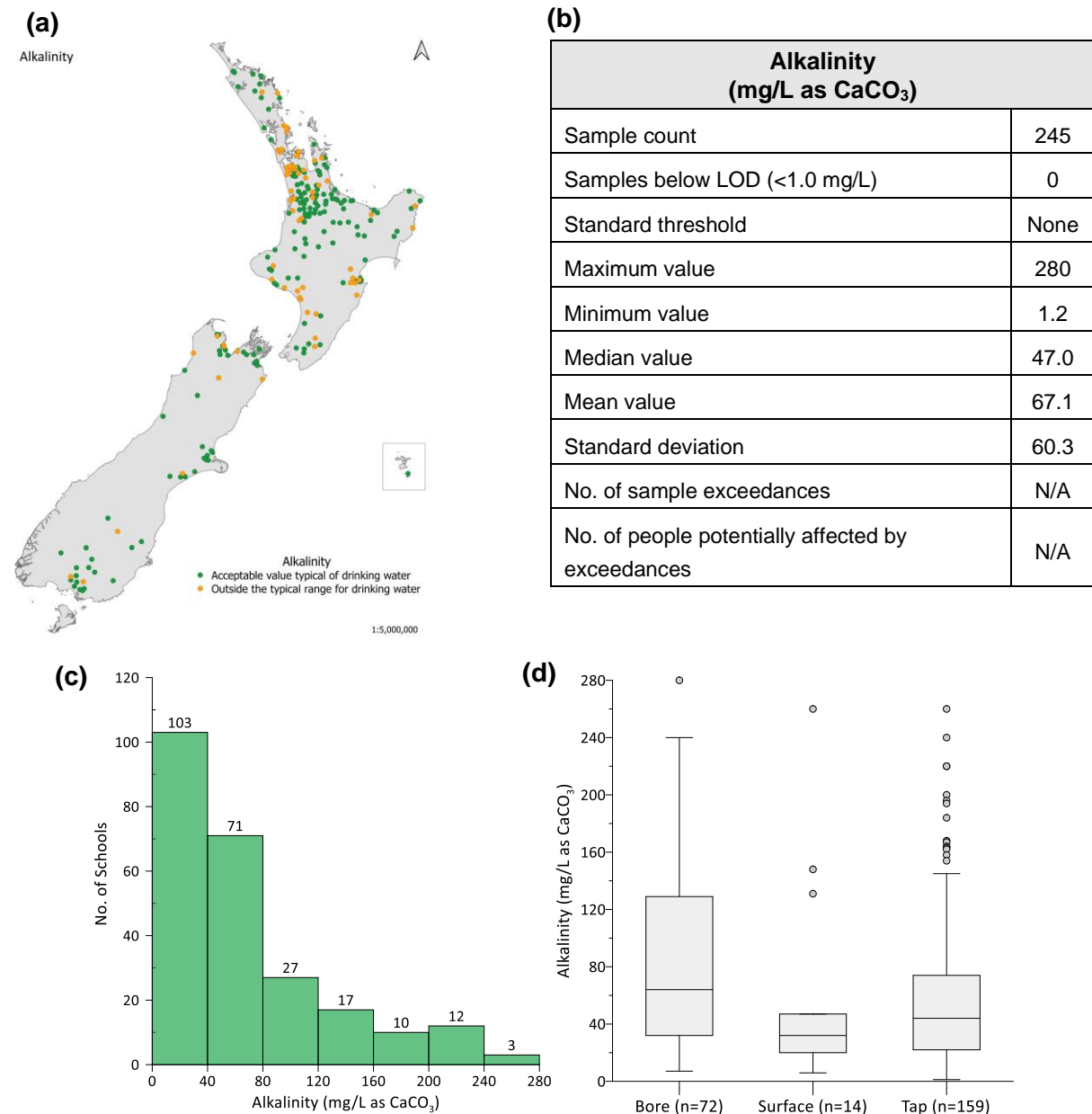


Figure 5.2 Rural school drinking-water alkalinity, measured in mg/L as CaCO₃. (a) Map of sampling site locations classified by the typical range of alkalinity in drinking water. (b) Alkalinity statistical data across the sites. (c) Alkalinity concentration histogram distribution. (d) Alkalinity concentration classed by water-sample type.

Most drinking water samples in this study are classed as having low alkalinity (<80 mg/L). The highest alkalinity was 280 mg/L, and the minimum value was 1.2 mg/L. While there is no specific threshold limit for alkalinity, a typical alkalinity range for drinking water is between 30 and 400 mg/L. Samples in this study generally fall within this range, and no extreme outliers were found. Median and mean alkalinity concentrations were relatively low (47.0 and 67.1 mg/L). Bore water had a higher mean alkalinity value (88.5 ± 69.0 mg/L) compared to surface water and treated tap water (59.9 ± 71.6 and 58.7 ± 52.7 mg/L, respectively). Tap water may have softeners added during the water-treatment process to reduce alkalinity and prevent pipe corrosion. Surface water exhibited the lowest alkalinity inter-quartile range, as surface-water sources are more consistent with rainfall-dominated recharge and have less water/rock interaction than bore (groundwater) sources, which are more likely to interact longer with limestones and/or gravels.

5.3 Ammonia

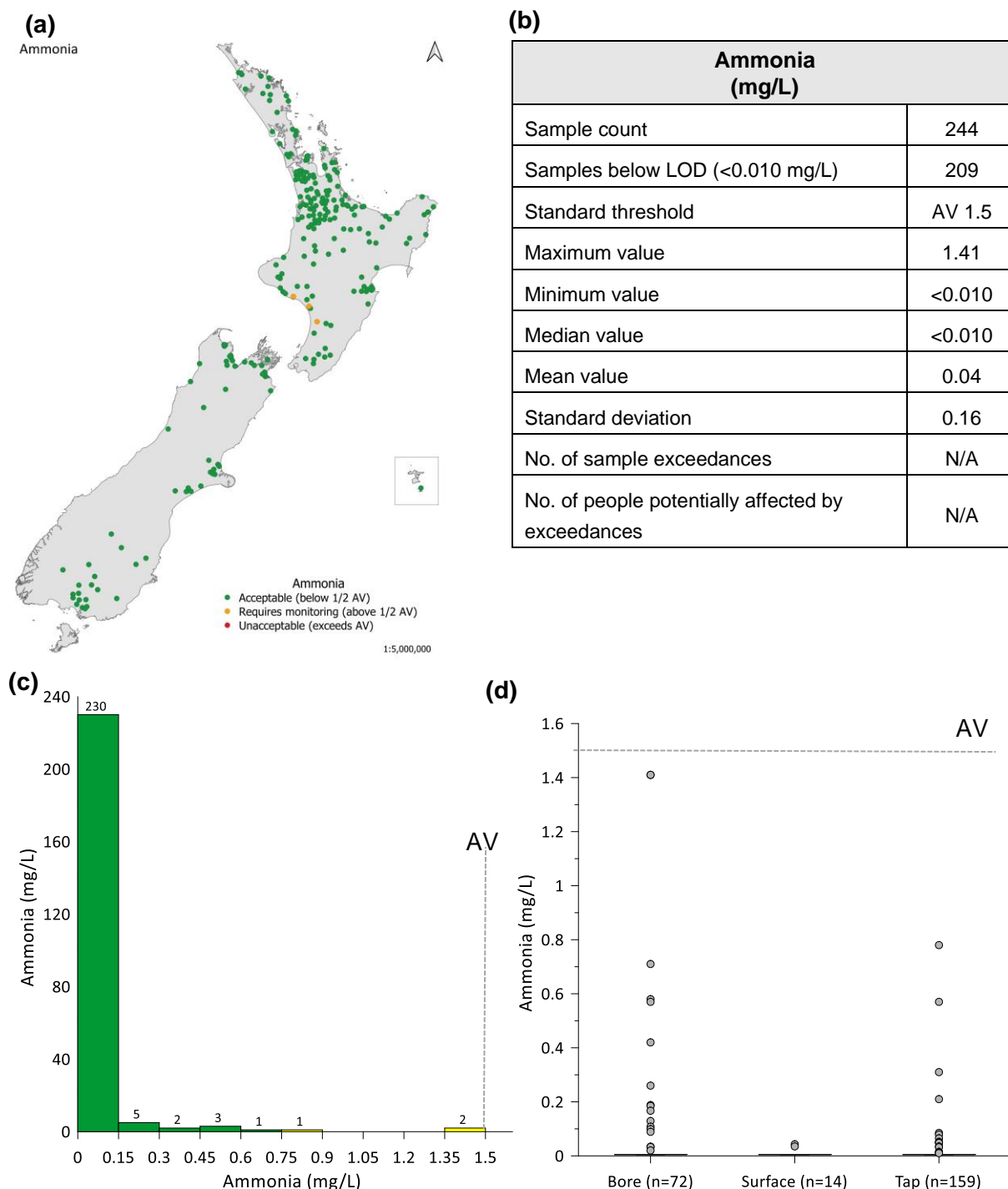


Figure 5.3 Rural school drinking-water ammonia, measured in mg/L. (a) Map of sampling site locations classified by the AV range of ammonia in drinking water. (b) Ammonia statistical data across the sites. (c) Ammonia concentration histogram distribution. (d) Ammonia concentration classed by water-sample type.

All samples were measured below the NZDWS AV for ammonia. The highest ammonia concentration was 1.41 mg/L, although most samples (209 out of 244) had levels below the LOD (<0.01 mg/L). There were only three samples with concentrations above ½ AV (>0.75 mg/L) at sites located around the Whanganui/Manawatū region. Ammonia concentrations in the surface-water samples had no significant outliers compared to bore and tap water, most likely as any ammonia in surface water quickly volatilises when exposed to atmosphere.

5.4 Antimony

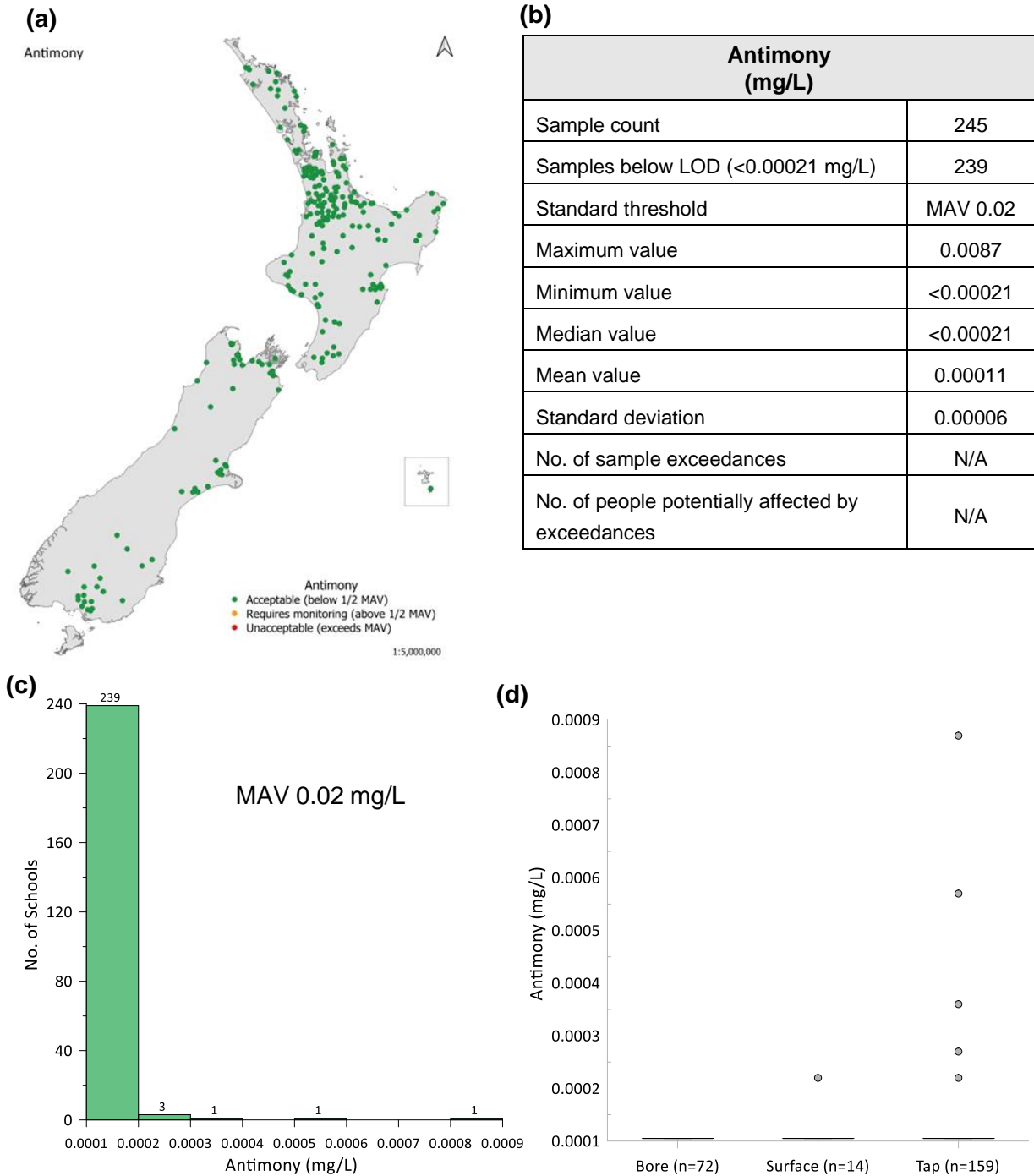


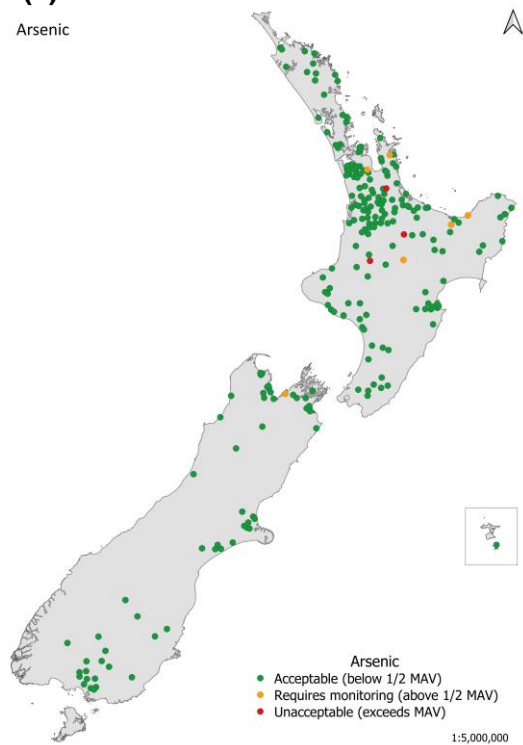
Figure 5.4 Rural school drinking-water antimony, measured in mg/L. (a) Map of sampling site locations classified by the AV range of antimony in drinking water. (b) Antimony statistical data across the sites. (c) Antimony concentration histogram distribution. (d) Antimony concentration classed by water-sample type.

All antimony concentrations in this study were below the LOD (< 0.00021 mg/L) except for six samples. The highest measured antimony concentration in drinking water was 0.0087 mg/L, which is still considerably below the NZDWS MAV of 0.02 mg/L. Five tap-water samples had detectable antimony, suggesting that, in New Zealand, antimony may be primarily introduced through plumbing and not through geogenic sources. A single spring (untreated source) sample had detectable antimony that may be environmentally related, as the site is located in the Rotorua region where there may be elemental contributions from volcanic soils and rocks.

5.5 Arsenic

(a)

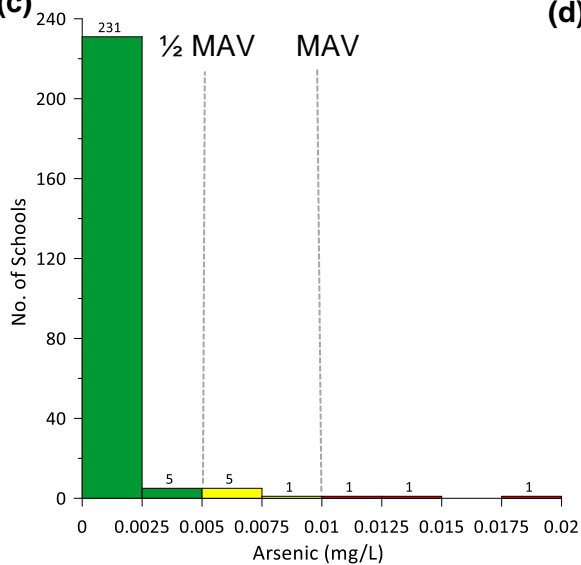
Arsenic



(b)

Arsenic (mg/L)	
Sample count	245
Samples below LOD (<0.0011 mg/L)	212
Standard threshold	MAV 0.01
Maximum value	0.01790
Minimum value	<0.0011
Median value	<0.0011
Mean value	0.00101
Standard deviation	0.00184
No. of sample exceedances	3
No. of people potentially affected by exceedances	301

(c)



(d)

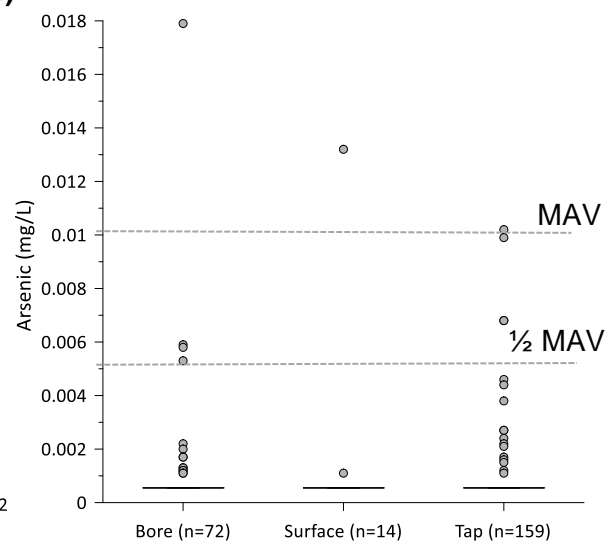


Figure 5.5 Rural school drinking-water arsenic, measured in mg/L. (a) Map of sampling site locations classified by New Zealand drinking-water standards. (b) Arsenic statistical data across the sites. (c) Arsenic concentration histogram distribution. (d) Arsenic concentration classed by water-sample type.

Arsenic was measured above the LOD (<0.0011 mg/L) at 33 out of 245 sites. Three sites detected arsenic at levels above the NZDWS MAV threshold of 0.01 mg/L, and six sites exceeded 1/2 MAV with values between 0.005 mg/L and 0.01 mg/L. Arsenic was found at high levels in all water types in this study (bore, surface water and treated tap water). Higher arsenic levels (above MAV) occurred in the Waikato region, and between 1/2 MAV and MAV in the Nelson, Pukekohe, Coromandel, Taupō and Bay of Plenty regions, where horticultural and farming activities are common, although the presence of elevated arsenic may be geologically related.

5.6 Boron

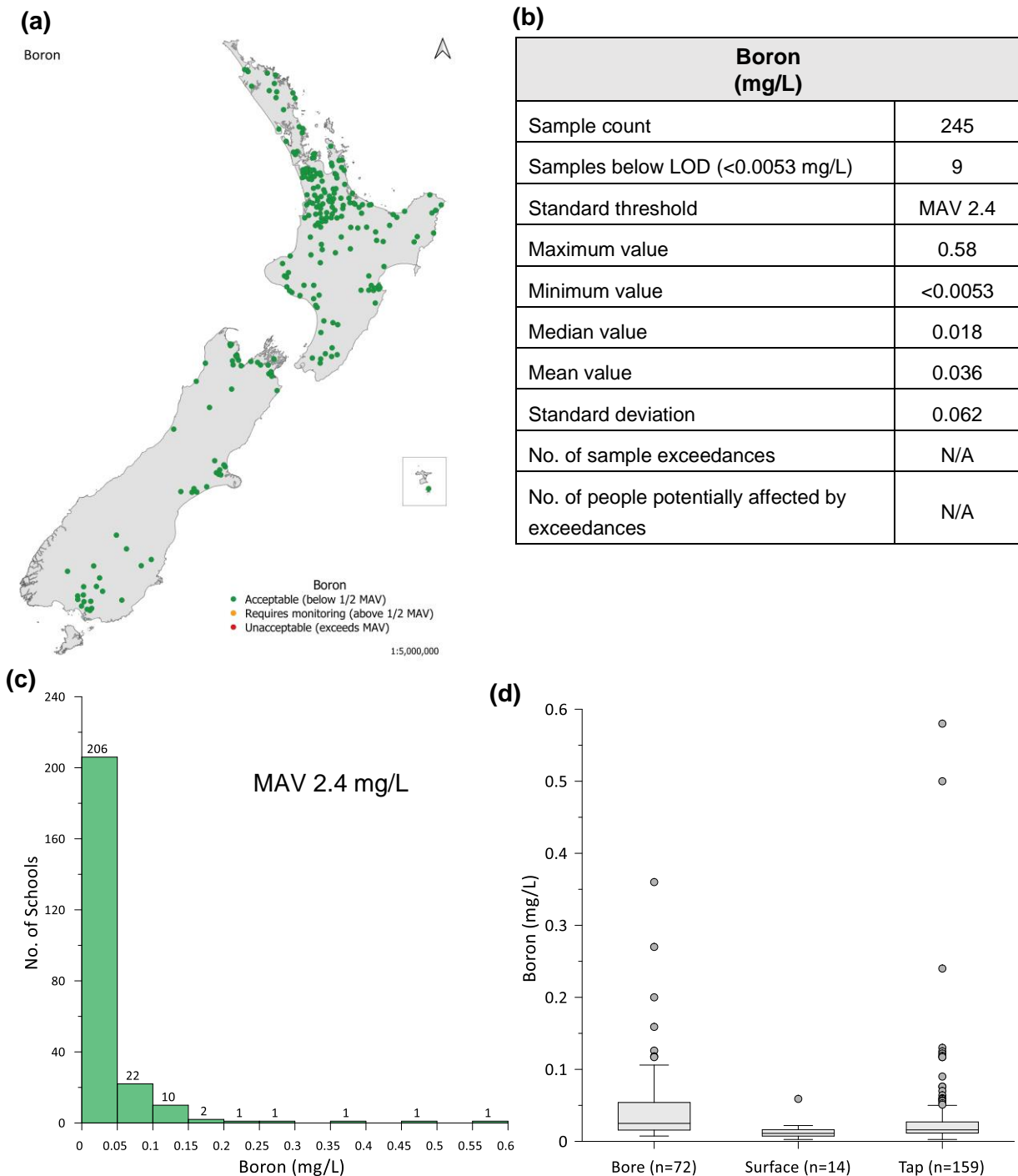


Figure 5.6 Rural school drinking-water boron, measured in mg/L. (a) Map of sampling site locations classified by New Zealand drinking-water standards. (b) Boron statistical data across the sites. (c) Boron concentration histogram distribution. (d) Boron concentration classed by water-sample type.

Boron was detected above LOD in 236 samples, with the highest concentration of 0.58 mg/L, which is considerably lower than the MAV threshold of 2.4 mg/L. Nine samples were below LOD (<0.0053 mg/L), and the median and mean boron values were 0.018 and 0.036 mg/L, respectively. Most samples had boron concentrations below 0.15 mg/L, with higher values found in both bore- and tap-water samples.

5.7 Cadmium

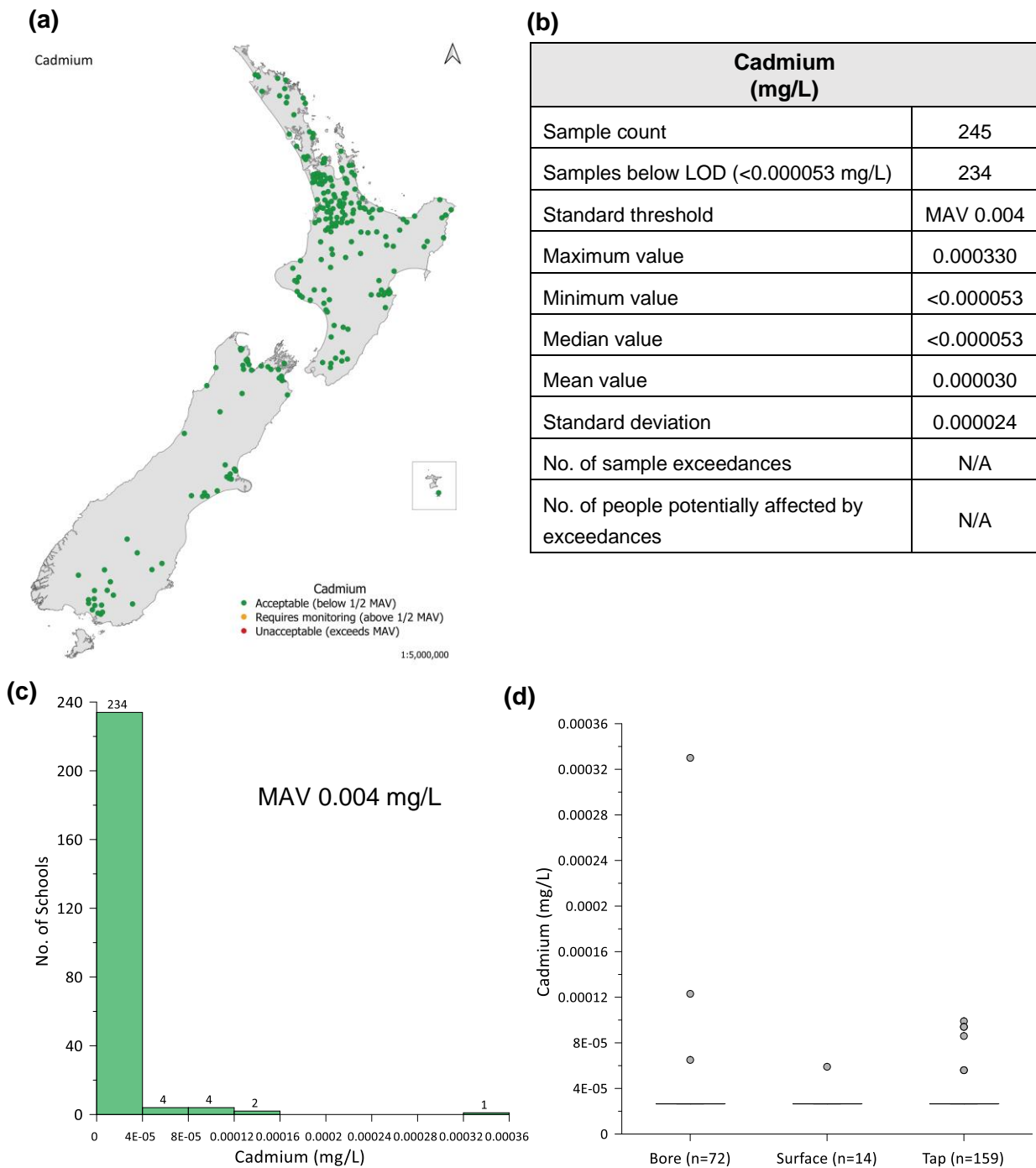


Figure 5.7 Rural school drinking-water cadmium, measured in mg/L. (a) Map of sampling site locations classified by New Zealand drinking-water standards. (b) Cadmium statistical data across the sites. (c) Cadmium concentration histogram distribution. (d) Cadmium concentration classed by water-sample type.

Cadmium was only detected in 11 samples (LOD of 0.000053 mg/L), with a highest concentration of 0.00033 mg/L, considerably below the NZDWS MAV (0.004 mg/L). Cadmium was detected in bore-, surface- and tap-water samples, suggesting that its origin is potentially both geogenic and anthropogenic.

5.8 Calcium

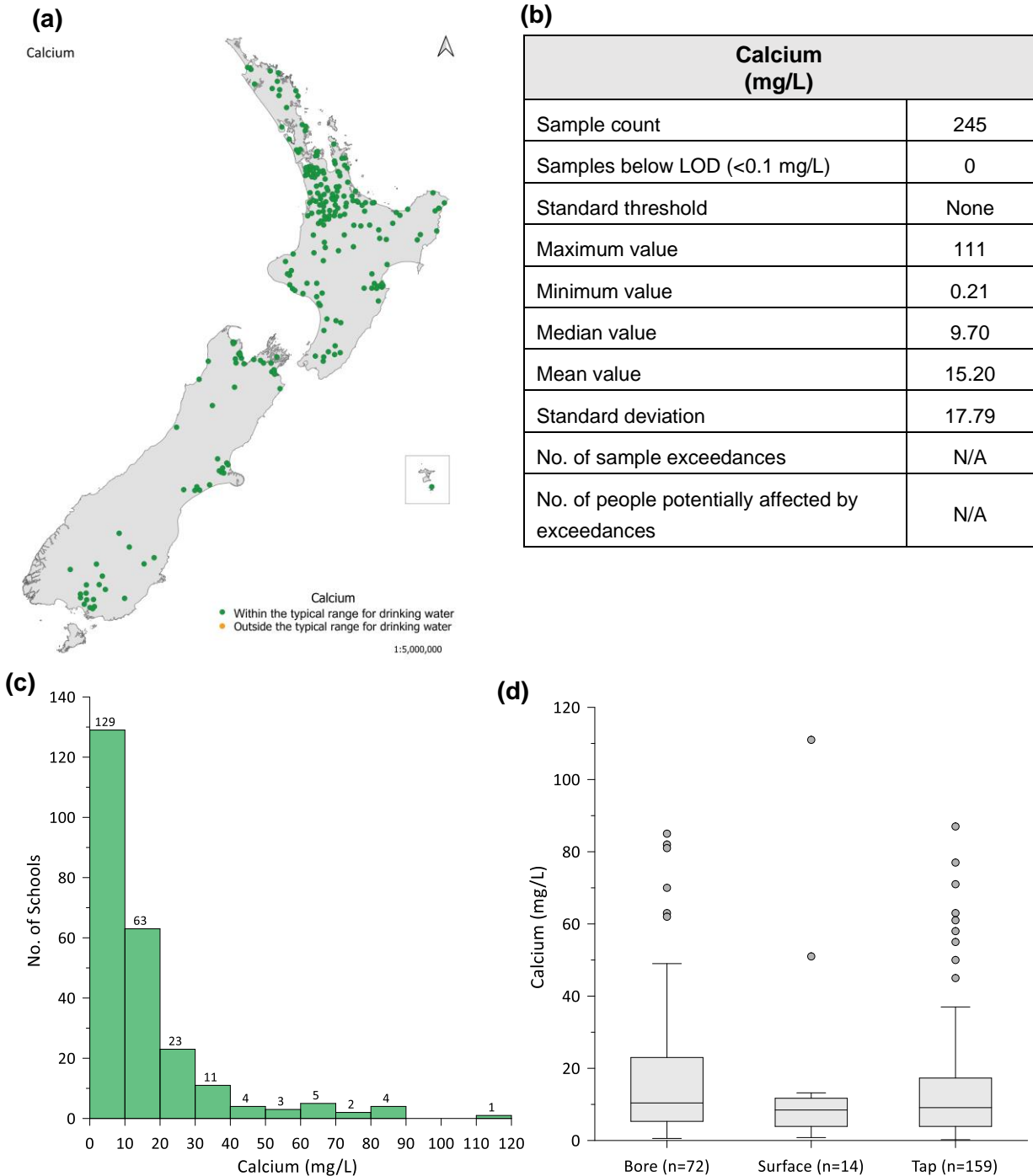


Figure 5.8 Rural school drinking-water calcium, measured in mg/L. (a) Map of sampling site locations classified by New Zealand drinking-water standards. (b) Calcium statistical data across the sites. (c) Calcium concentration histogram distribution. (d) Calcium concentration classed by water-sample type.

Calcium levels in drinking-water samples ranged from 0.21 to 111 mg/L, with a median and mean value of 9.7 and 15.2 mg/L, respectively. Most values were below 20 mg/L, which is lower than the typical calcium range in drinking water from 0 to 80 mg/L (World Health Organisation 2009). There were no samples below LOD. Surface-water concentrations exhibited a narrower range of calcium values than those of bore and tap water. Similar to alkalinity, surface water had a narrower inter-quartile range, while bore- and tap-water sources had a higher upper quarter range with more outliers. Higher calcium concentrations in bore water is expected due to water/rock interaction.

5.9 Chloride

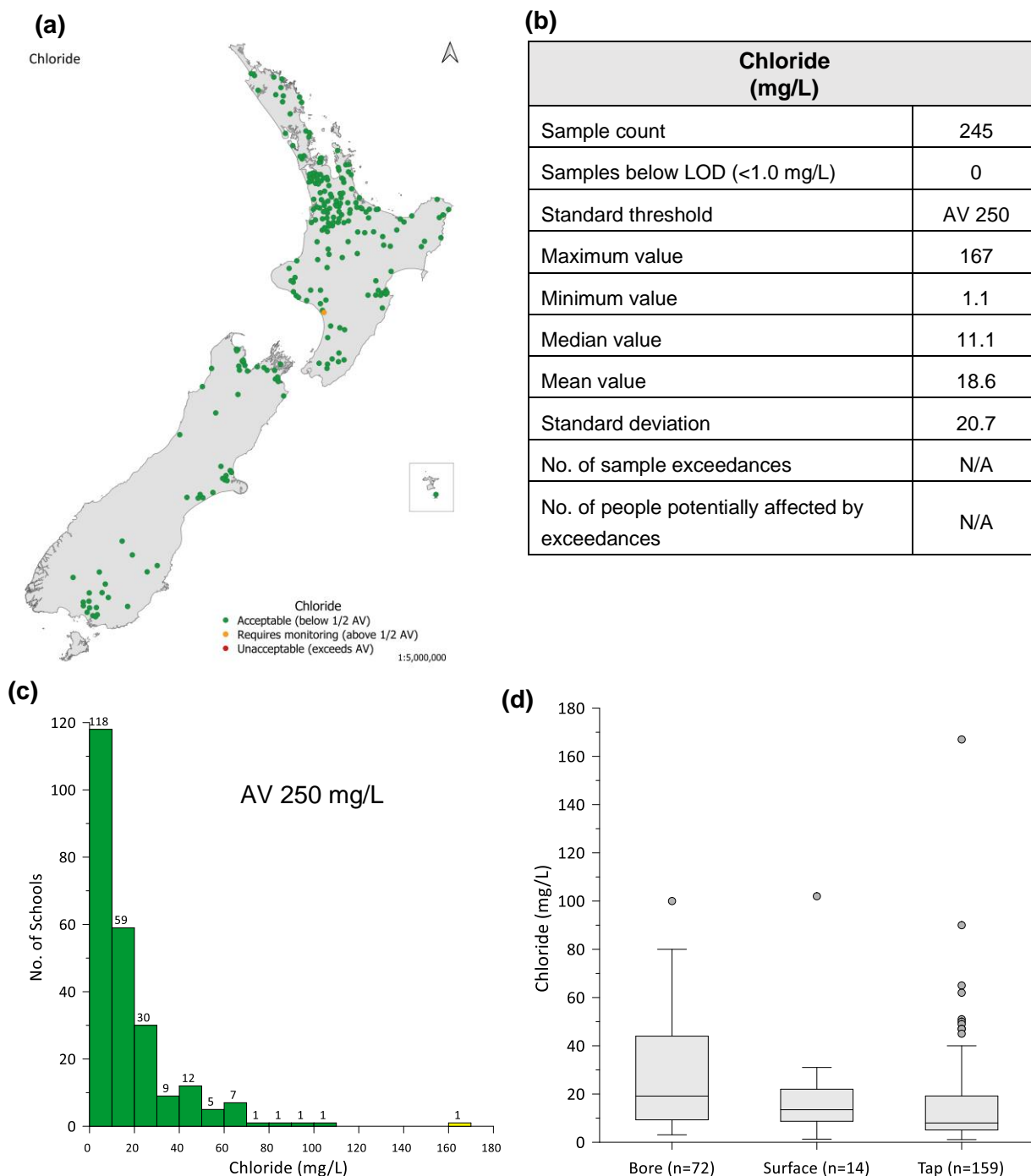


Figure 5.9 Rural school drinking-water chloride, measured in mg/L. (a) Map of sampling site locations classified by New Zealand drinking-water standards. (b) Chloride statistical data across the sites. (c) Chloride concentration histogram distribution. (d) Chloride concentration classed by water-sample type.

All chloride concentrations were found below the AV of 250 mg/L. A tap-water sample from the Whanganui region was above ½ AV and had the highest chloride concentration in this study at 167 mg/L. The lowest chloride value was 1.1 mg/L and the median and mean were low, at 11.1 and 18.6 mg/L. Most samples had chloride values below 40 mg/L, although the chloride inter-quartile range was lower for tap and surface water than bore water.

5.10 Chromium

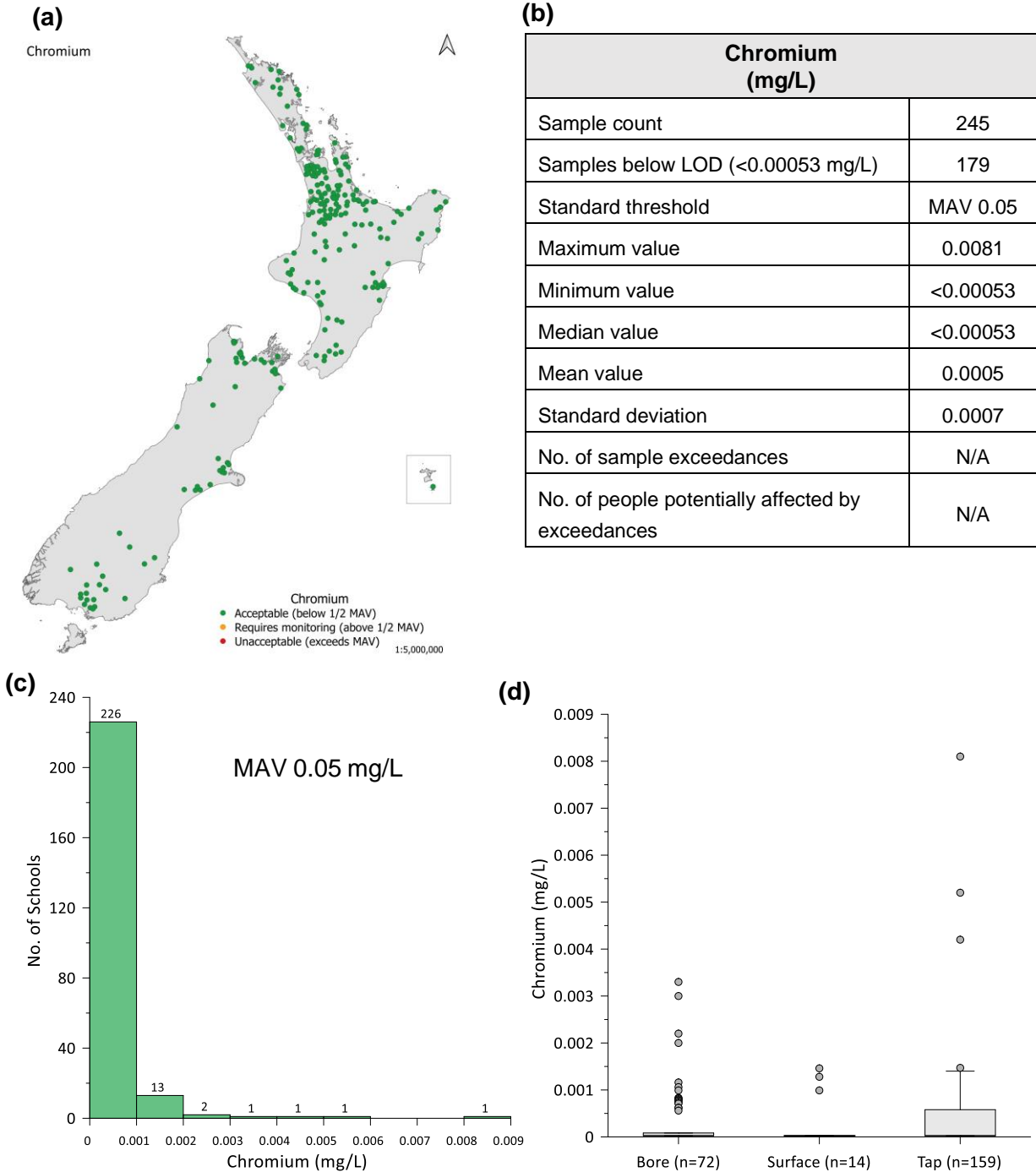


Figure 5.10 Rural school drinking-water chromium, measured in mg/L. (a) Map of sampling site locations classified by New Zealand drinking-water standards. (b) Chromium statistical data across the sites. (c) Chromium concentration histogram distribution. (d) Chromium concentration classed by water-sample type.

Chromium concentrations were measured at all sites below the MAV of 0.05 mg/L with 179 samples below LOD. The highest chromium value was 0.0081 mg/L, found in tap water. The median was the LOD, and the mean value was 0.0005 mg/L. Chromium was found in all three water-source types (bore, surface and tap water), suggesting that these minor occurrences may not only be related to plumbing sources but could also be geogenic or anthropogenic.

5.11 Conductivity

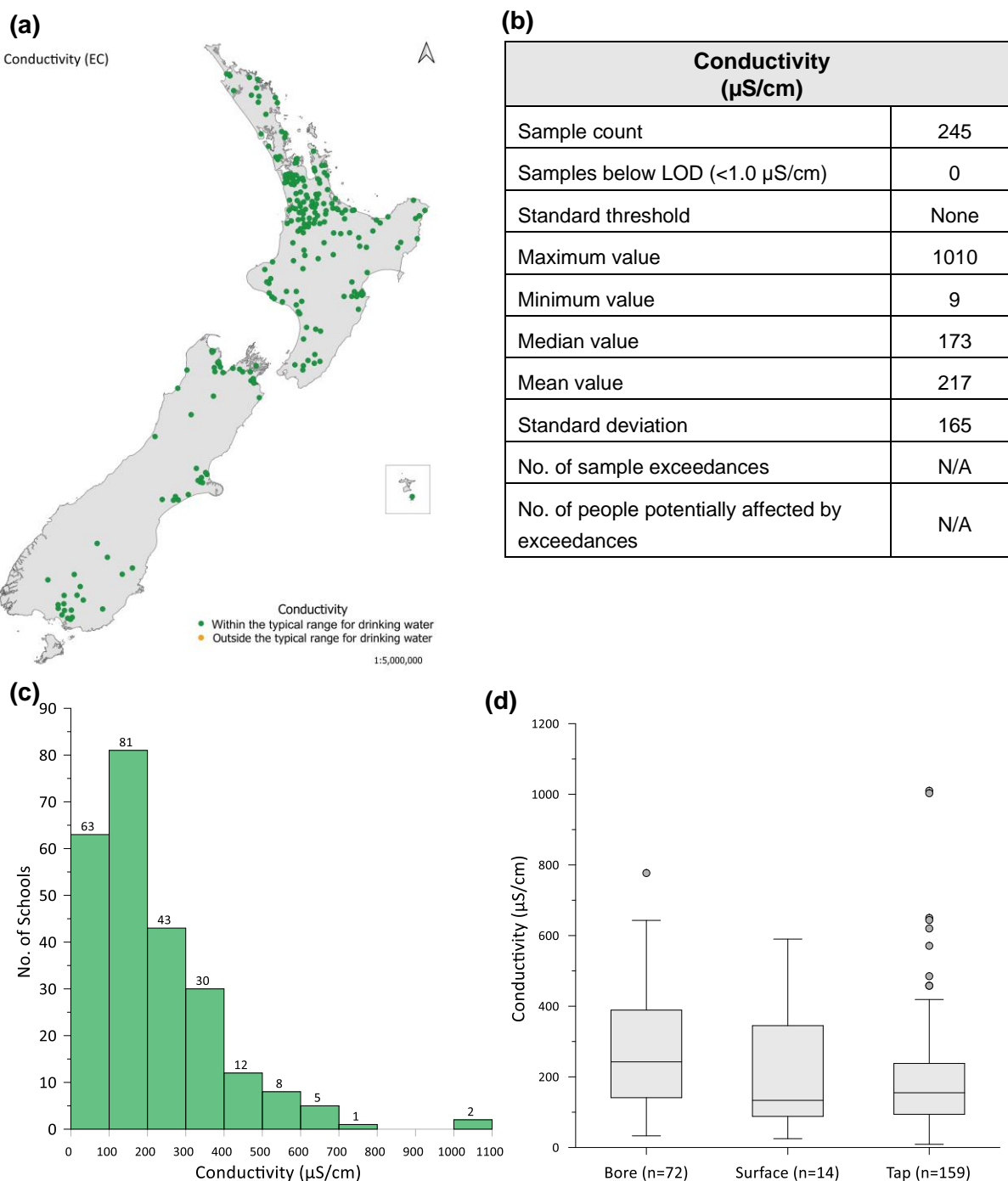


Figure 5.11 Rural school drinking-water conductivity, measured in $\mu\text{S}/\text{cm}$. (a) Map of sampling site locations classified by New Zealand drinking-water standards. (b) Conductivity statistical data across the sites. (c) Conductivity concentration histogram distribution. (d) Conductivity concentration classed by water-sample type.

Conductivity was measured below $400 \mu\text{S}/\text{cm}$ at most sites, which is within a typical range for drinking water. The minimum conductivity found in rural drinking water was $9 \mu\text{S}/\text{cm}$, suggesting that the supply was sourced from rainwater. Two tap-water samples were measured above $1000 \mu\text{S}/\text{cm}$, with a maximum conductivity of $1010 \mu\text{S}/\text{cm}$. A further school had bore water with a conductivity of $777 \mu\text{S}/\text{cm}$, which is also likely to be from groundwater mineralisation if the sample was taken prior to any water-treatment process. Bore water samples exhibited higher median and mean conductivity and a larger conductivity range than surface-water samples.

5.12 Copper

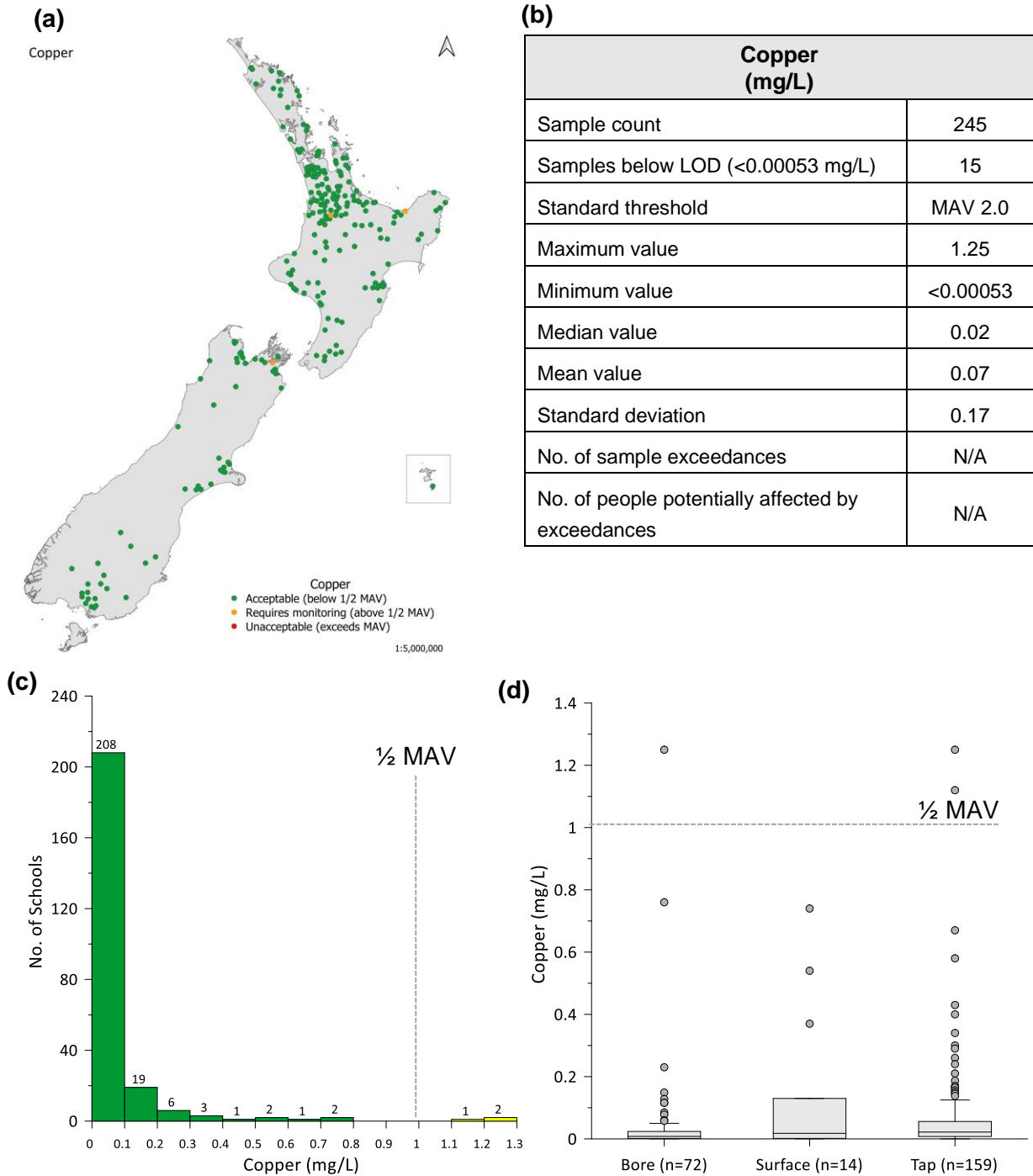


Figure 5.12 Rural school drinking-water copper, measured in mg/L. (a) Map of sampling site locations classified by New Zealand drinking-water standards. (b) Copper statistical data across the sites. (c) Copper concentration histogram distribution. (d) Copper concentration classed by water-sample type.

Copper concentrations were all below MAV of 2.0 mg/L, with 16 samples below LOD. The highest copper concentration was 1.25 mg/L, found in both a bore- and tap-water sample. In total, three samples had copper concentrations above $\frac{1}{2}$ MAV; these were from the Waikato / Bay of Plenty and Nelson areas. Most samples had copper values below 0.2 mg/L, with a median of 0.02 mg/L and a mean of 0.07 mg/L. Higher-outlier copper values were found in all three water-source types (bore, surface and tap water), suggesting that these minor occurrences are not only related to plumbing sources but also geogenic or anthropogenic ones and are not removed by existing water-treatment systems.

5.13 *Escherichia coli*

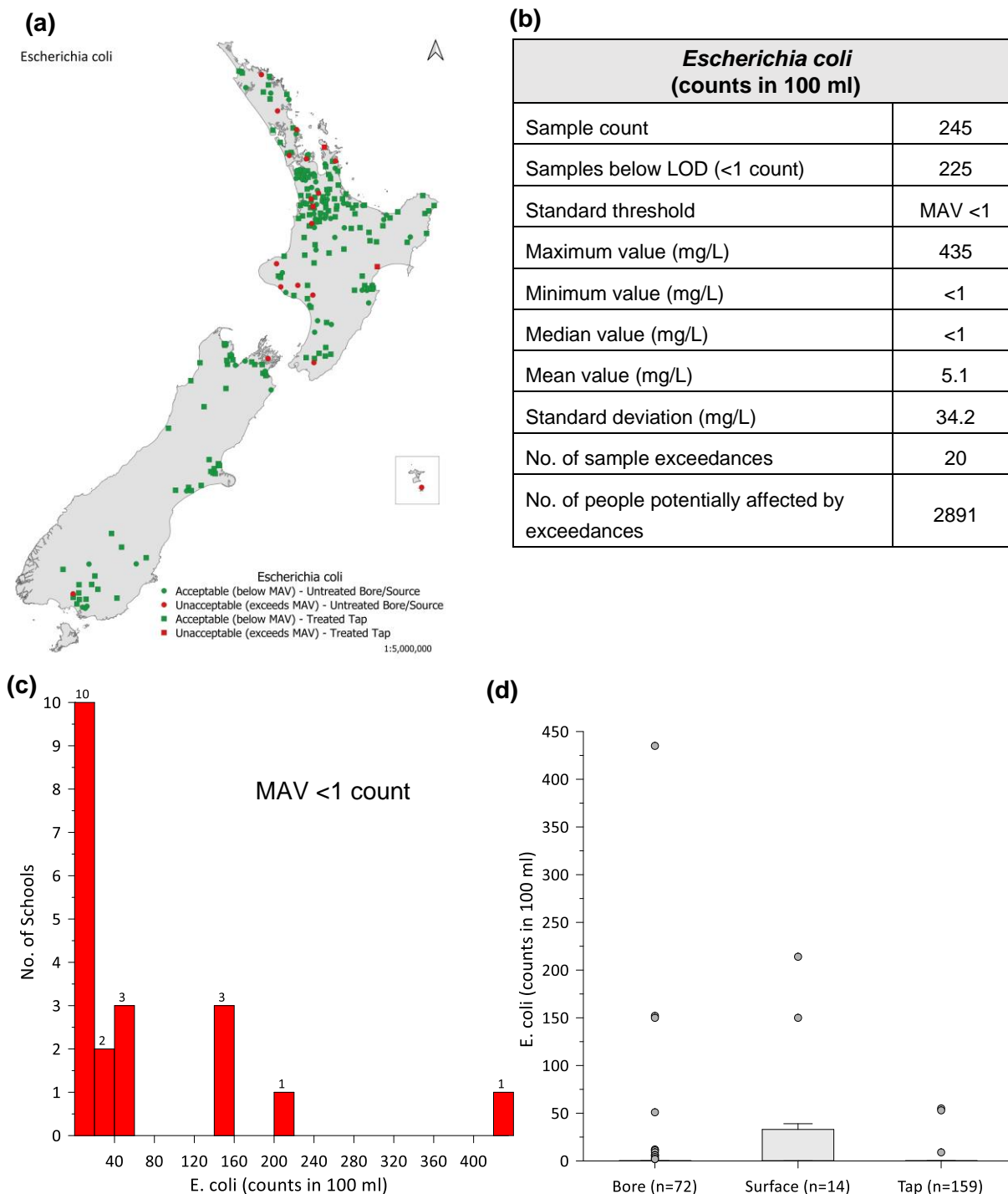


Figure 5.13 Rural school drinking-water *Escherichia coli*, measured in counts in 100 mL. (a) Map of sampling site locations classified by New Zealand drinking-water standards. (b) *Escherichia coli* statistical data across the sites. (c) *Escherichia coli* count histogram distribution. (d) *Escherichia coli* count classed by water-sample type.

MAV exceedances of *Escherichia coli* (*E. coli*) were detected at 20 schools (≥ 1 or more counts), with the highest value of 435 counts. Of these 20 MAV exceedances, 15 samples did not arrive at the laboratory chilled to below 10°C, including most of the higher *E. coli* count samples. Of the 20 MAV exceedances, 12 exceedances were from untreated bore water and five were from springs (surface water). Three samples were from treated tap water.

5.14 Fluoride

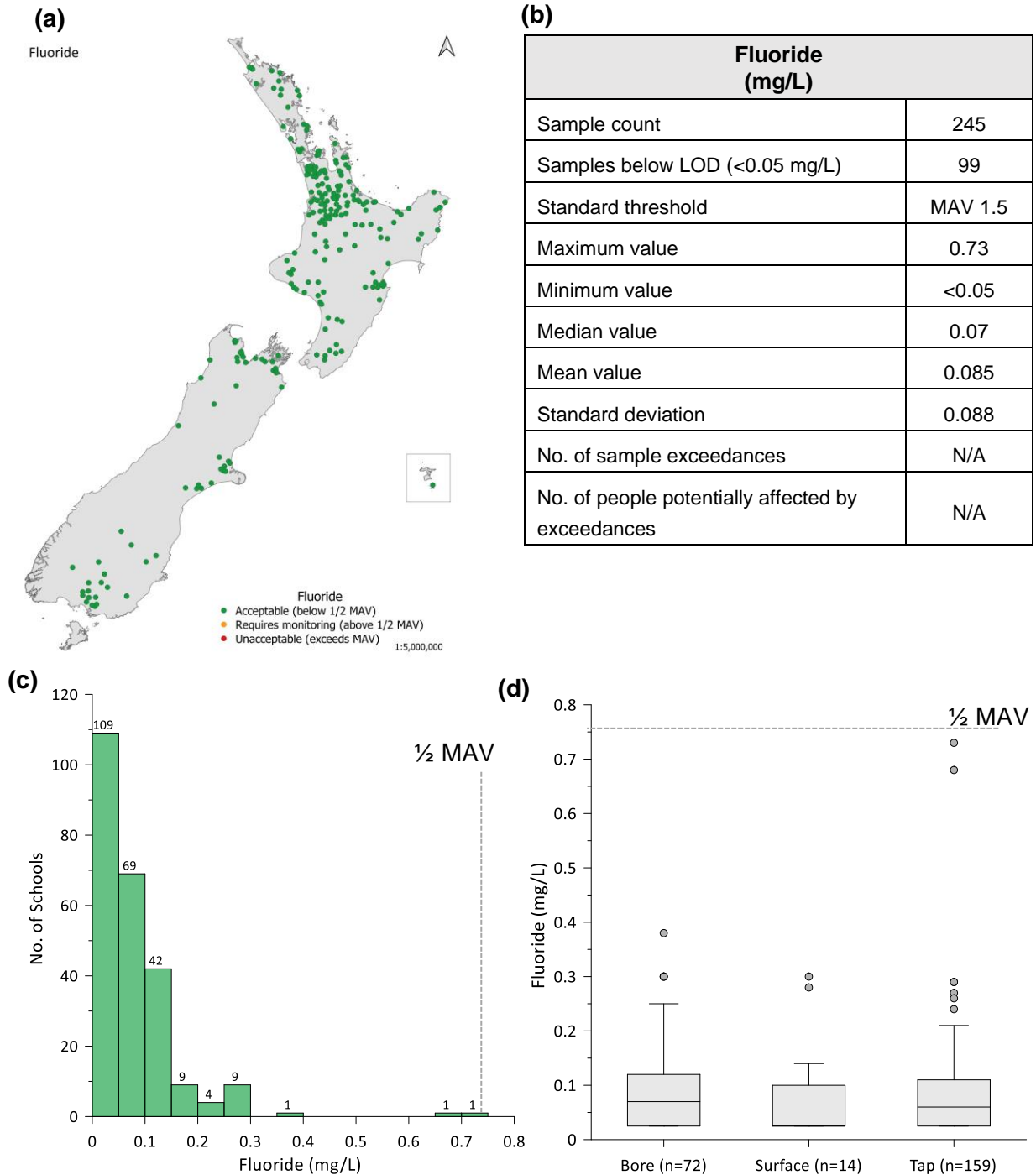


Figure 5.14 Rural school drinking-water fluoride, measured in mg/L. (a) Map of sampling site locations classified by New Zealand drinking-water standards. (b) Fluoride statistical data across the sites. (c) Fluoride concentration histogram distribution. (d) Fluoride concentration classed by water-sample type.

Fluoride concentrations all measured below the MAV of 1.5 mg/L, with 99 samples below LOD. The highest fluoride values were 0.73 and 0.68 mg/L found in tap water, but these levels were below 1/2 MAV. Most water samples had fluoride values below 0.15 mg/L, with a median of 0.07 mg/L and a mean of 0.0085 mg/L. High-outlier fluoride values were found in all three water-source types (bore, surface and tap water). Fluoride is not added to rural school drinking-water sources, so all detectable fluoride arises from natural geological sources.

5.15 Free Carbon Dioxide

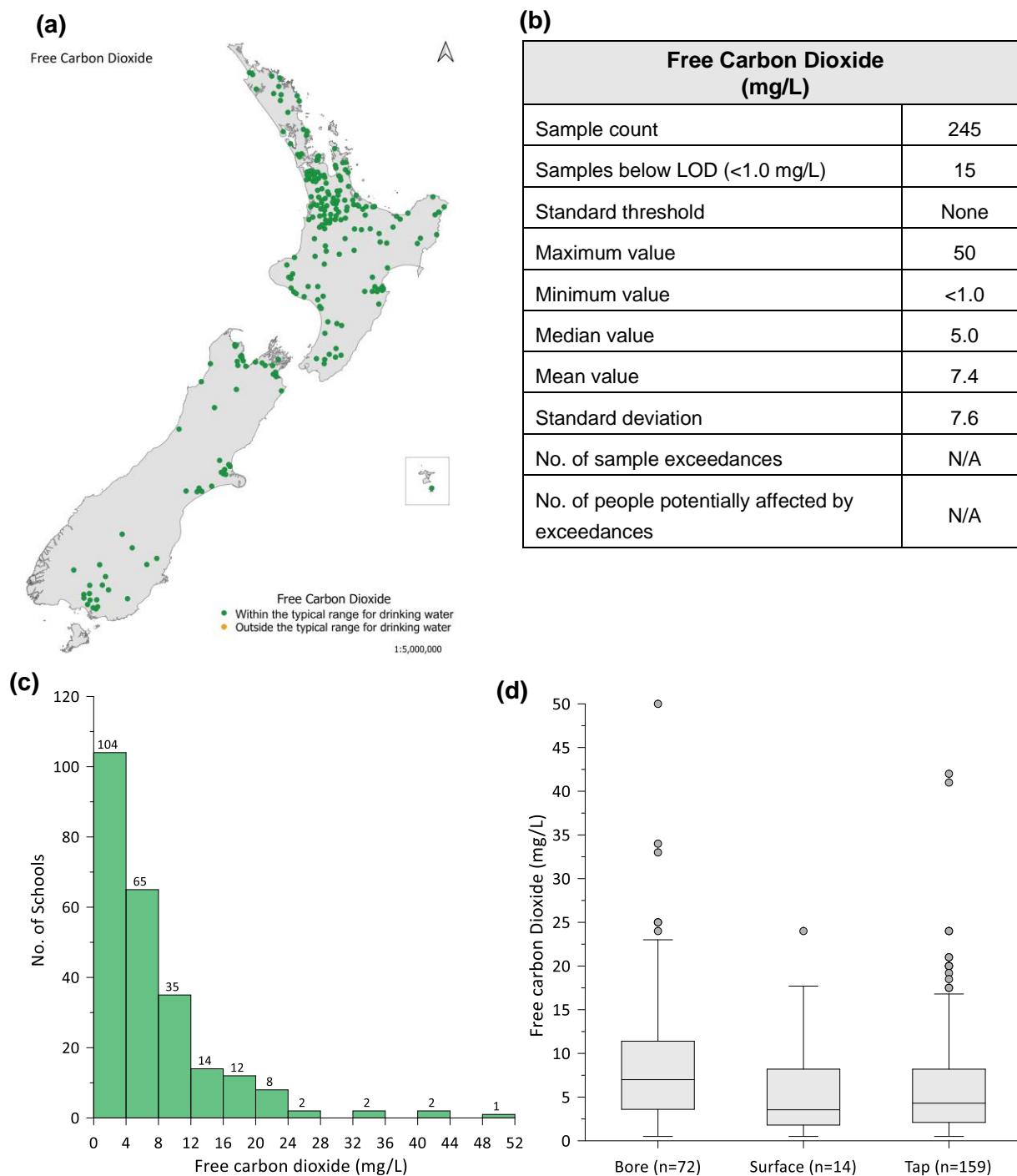


Figure 5.15 Rural school drinking-water free carbon dioxide, measured in mg/L. (a) Map of sampling site locations classified by New Zealand drinking-water standards. (b) Free carbon dioxide statistical data across the sites. (c) Free carbon dioxide concentration histogram distribution. (d) Free carbon dioxide concentration classed by water-sample type.

Free carbon dioxide concentrations ranged from below LOD to 50 mg/L, with 15 samples below LOD. The highest free carbon dioxide values were found in bore and tap water, although there is no recommended guideline threshold for free carbon dioxide in drinking water. Most water samples had free carbon dioxide values below 12 mg/L, with a median of 5 mg/L and a mean of 7.4 mg/L. High-outlier free carbon dioxide values were more common in bore water than surface and tap water, suggesting that degassing of CO₂ may occur if the source water sits exposed to atmospheric conditions.

5.16 Hardness

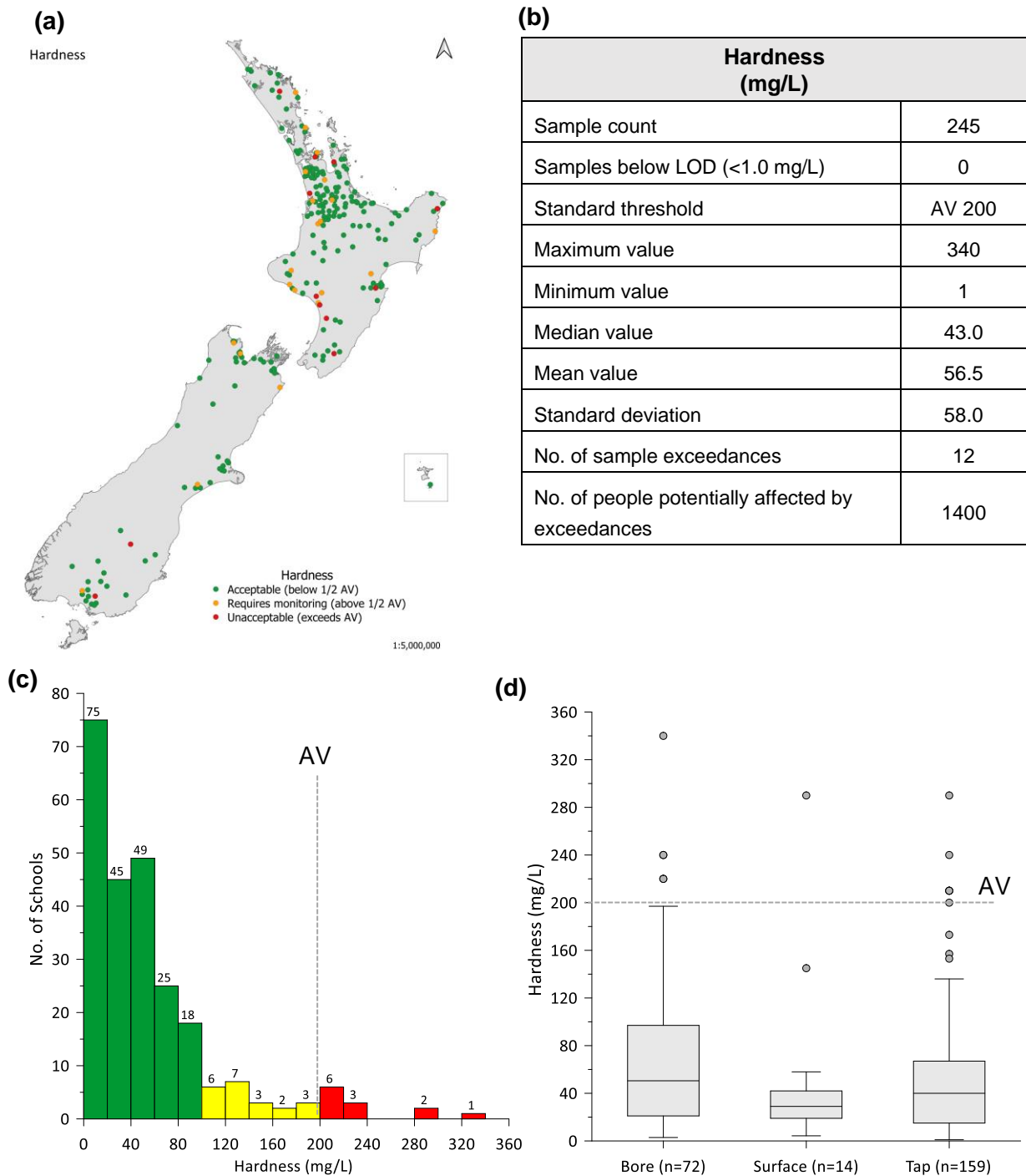


Figure 5.16 Rural school drinking-water hardness, measured in mg/L. (a) Map of sampling site locations classified by New Zealand drinking-water standards. (b) Hardness statistical data across the sites. (c) Hardness concentration histogram distribution. (d) Hardness concentration classed by water-sample type.

Water hardness ranged from 1 mg/L to 340 mg/L, with 12 AV exceedances over 200 mg/L. The highest hardness value was found in bore water, but high outliers were also found in surface water and tap water. Most water samples had hardness values below 100 mg/L, with a median of 43.0 mg/L and a mean of 58.0 mg/L.

5.17 Iron

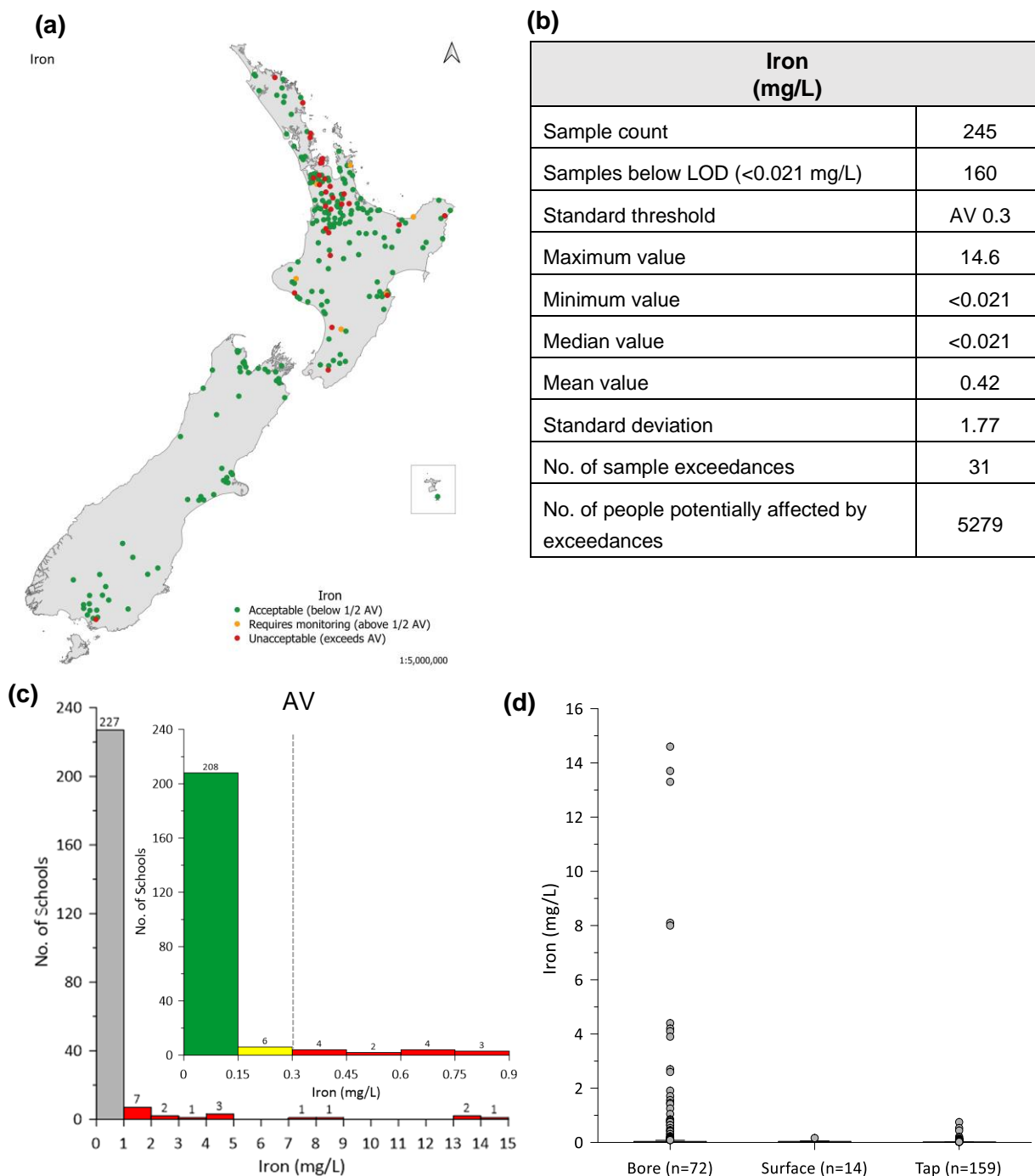


Figure 5.17 Rural school drinking-water iron, measured in mg/L. (a) Map of sampling site locations classified by New Zealand drinking-water standards. (b) Iron statistical data across the sites. (c) Iron concentration histogram distribution. (d) Iron concentration classed by water-sample type.

Iron concentrations measured in this study ranged from below LOD to 14.6 mg/L, with 160 samples measured below LOD and 31 samples measured above AV. The highest iron values were found in unfiltered bore water, with 28 AV exceedances. However, three tap water samples also exceeded AV. Most water samples had iron values below LOD (<0.0021 mg/L), with a median of <0.0021 mg/L and an artificially higher mean of 0.42 mg/L due to the inclusion of the large exceedances. Most iron exceedances were in the upper North Island, above the Waikato region. The large number of exceedances emphasise the need for appropriate treatment and maintenance to avoid aesthetic and disinfection impacts on drinking water supplies.

5.18 Lead

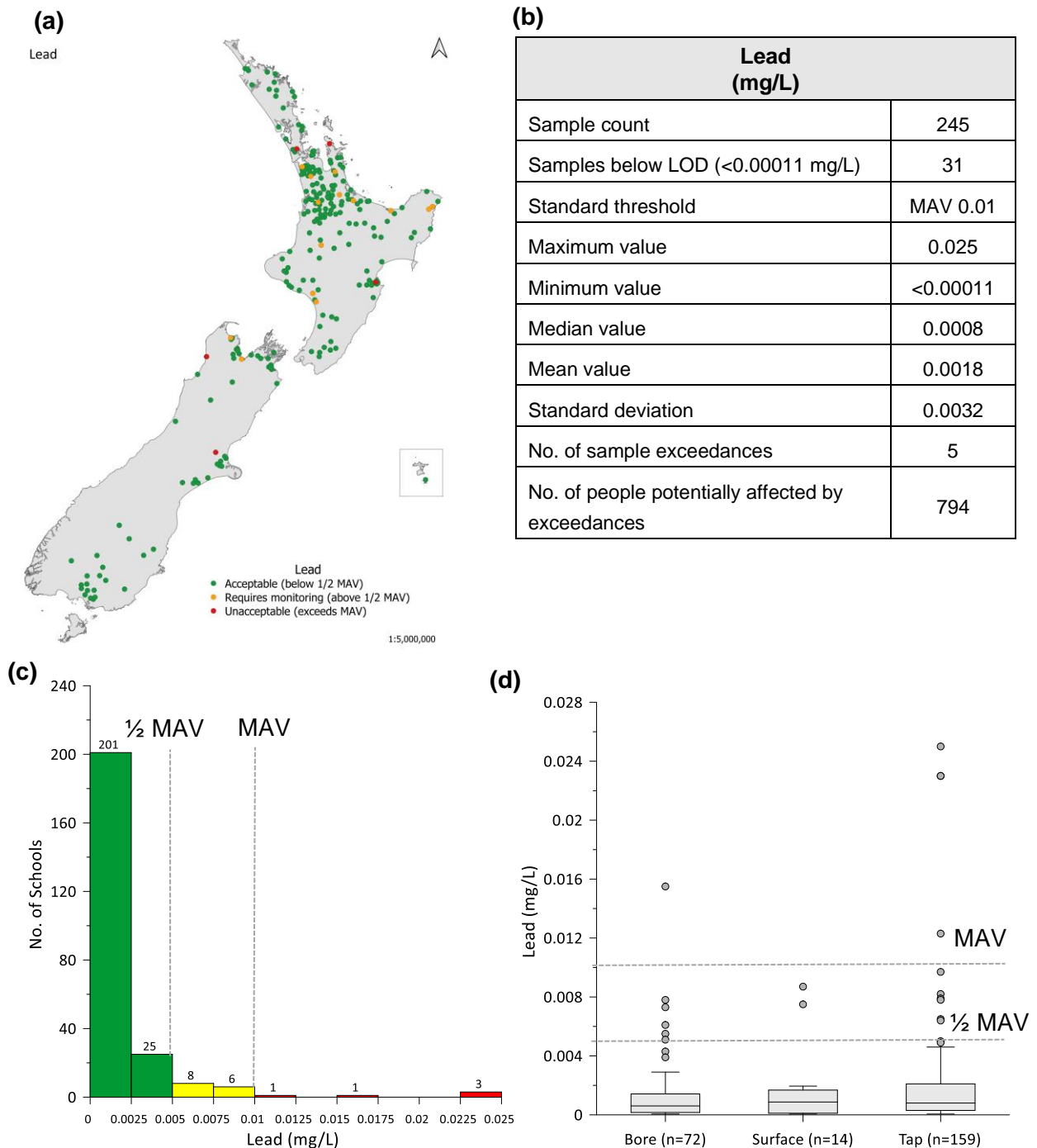


Figure 5.18 Rural school drinking-water lead, measured in mg/L. (a) Map of sampling site locations classified by New Zealand drinking-water standards. (b) Lead statistical data across the sites. (c) Lead concentration histogram distribution. (d) Lead concentration classed by water sample type.

Lead concentrations ranged from below LOD to 0.025 mg/L, with 31 samples below LOD and five samples measured above MAV. The highest lead concentrations were found in tap water, with four out of five MAV exceedances. However, a bore-water sample also exceeded MAV. Most water samples had low lead values, with a median of 0.0008 mg/L and a mean of 0.0018 mg/L. Three lead exceedances were in the North Island and two in the South Island. A further 14 samples registered lead values between 1/2 MAV and MAV.

5.19 Magnesium

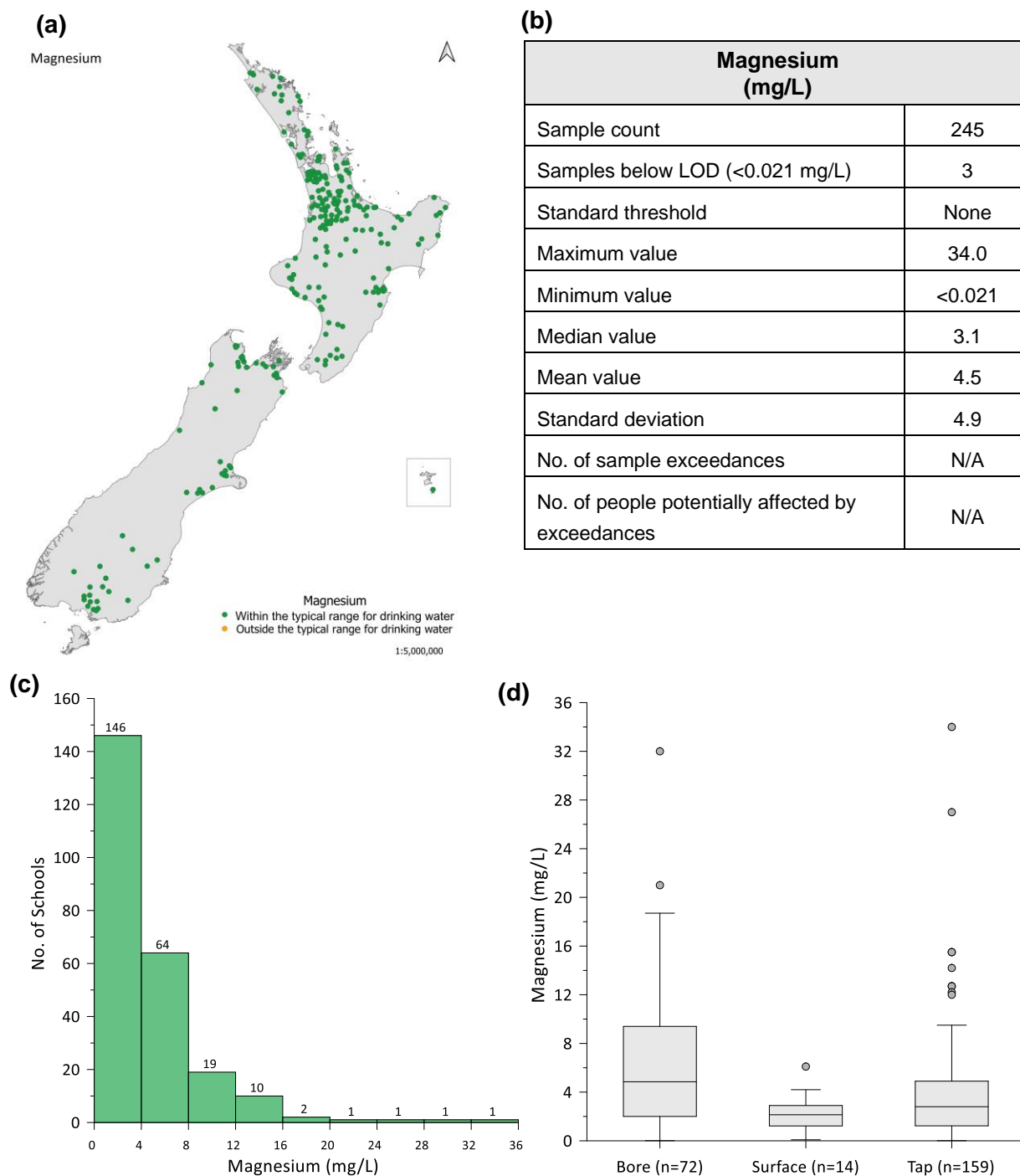


Figure 5.19 Rural school drinking-water magnesium, measured in mg/L. (a) Map of sampling site locations classified by New Zealand drinking-water standards. (b) Magnesium statistical data across the sites. (c) Magnesium concentration histogram distribution. (d) Magnesium concentration classed by water-sample type.

Magnesium concentrations ranged from below LOD to 34.0 mg/L. While there are no guideline thresholds set for magnesium concentrations in drinking water, various international agencies suggest that 10–50 mg/L is acceptable (World Health Organisation 2009). The highest magnesium values (>20 mg/L) were found in both bore and tap water. Most samples had magnesium values below 8 mg/L, with a median of 3.1 mg/L and a mean of 4.5 mg/L. Magnesium was found to have a larger inter-quartile range in bore water than in surface and tap water.

5.20 Manganese

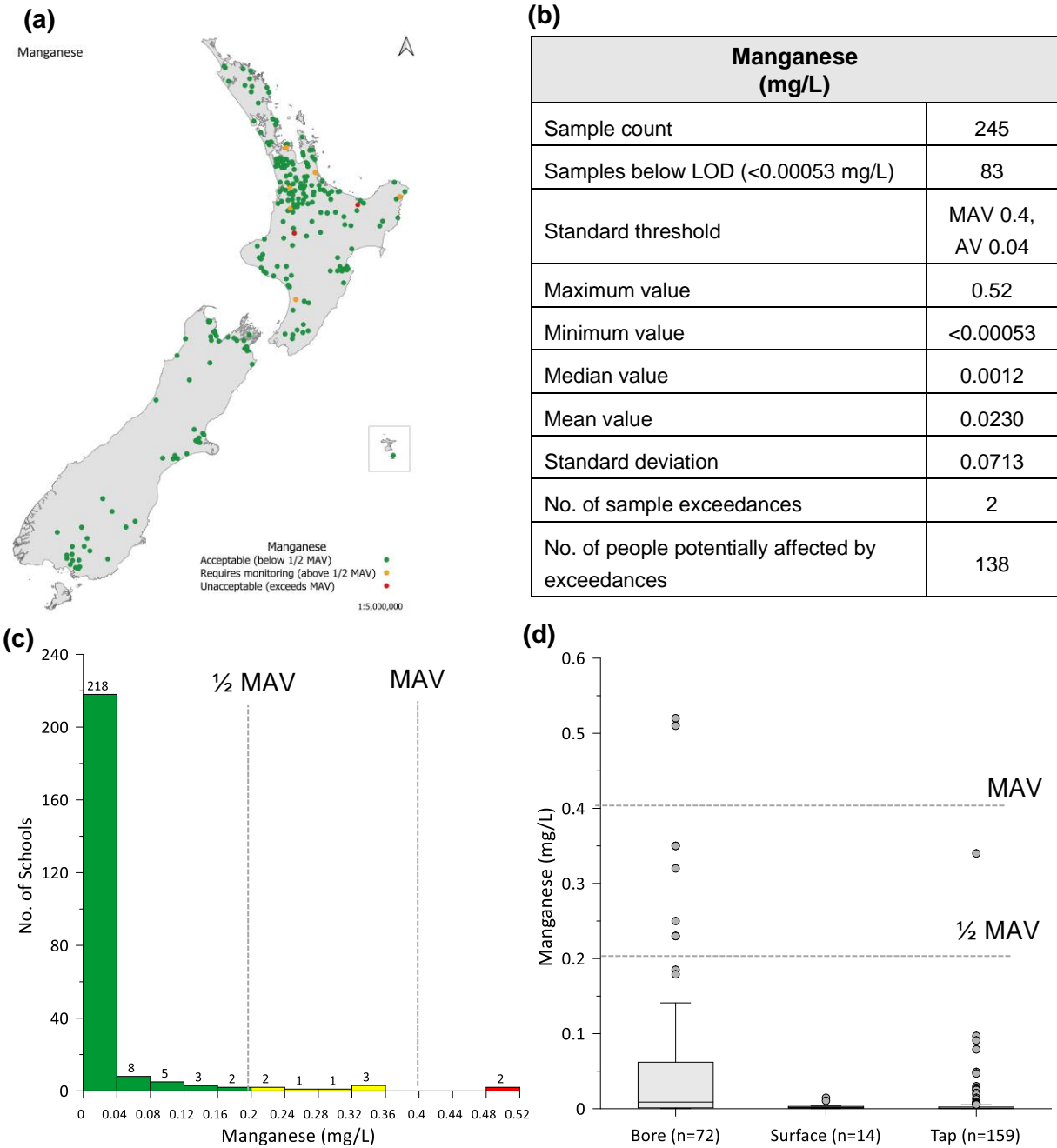


Figure 5.20 Rural school drinking-water manganese, measured in mg/L. (a) Map of sampling site locations classified by New Zealand drinking-water standards. (b) Manganese statistical data across the sites. (c) Manganese concentration histogram distribution. (d) Manganese concentration classed by water-sample type.

Manganese concentrations were measured below LOD values for 83 samples, with a median of 0.0012 mg/L and a mean of 0.0230 mg/L. The highest manganese concentration was 0.52 mg/L found in bore water. Two samples had manganese concentrations above MAV (>0.4 mg/L), and seven samples had values between 1/2 MAV and MAV. All MAV and 1/2 MAV exceedances were in the North Island.

Twenty-eight samples had AV exceedances (>0.04 mg/L). These samples were in the North Island. Outlier manganese values were found primarily in bore water but also occurred in tap water, suggesting that manganese is primarily geogenic in origin and is not always effectively removed by water filtration systems.

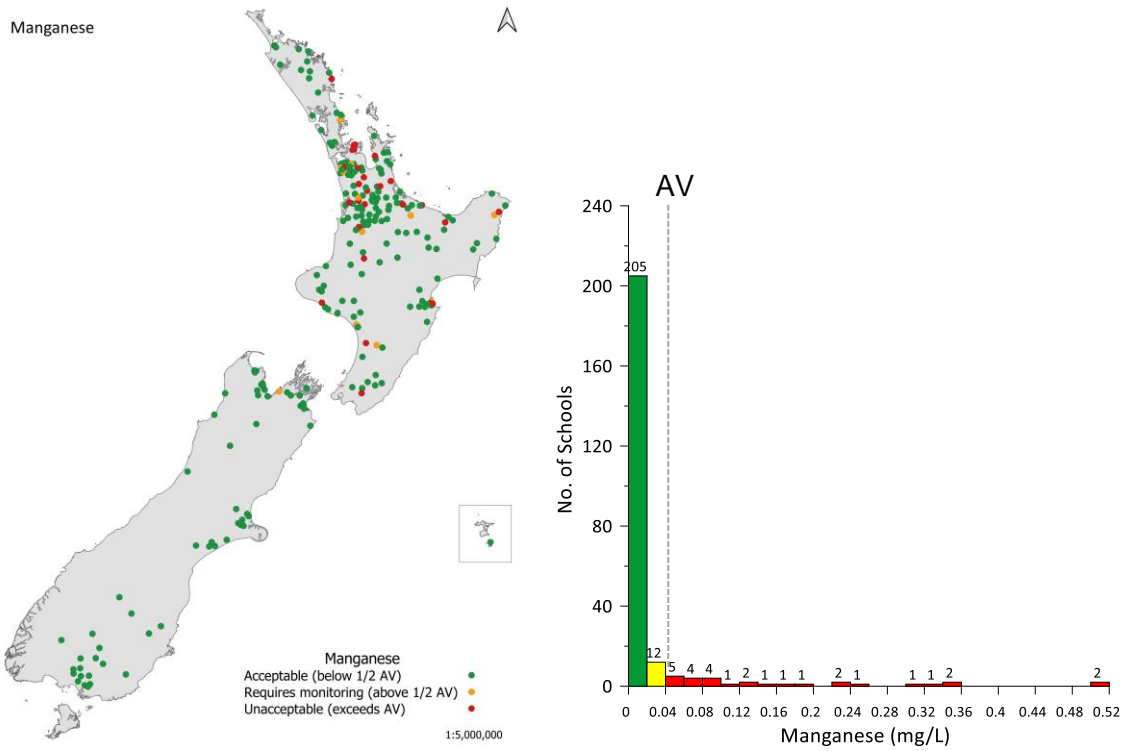


Figure 5.21 Rural school drinking-water manganese, measured in mg/L, compared to AV (left); manganese concentration histogram distribution compared to the AV guideline (right).

5.21 Mercury

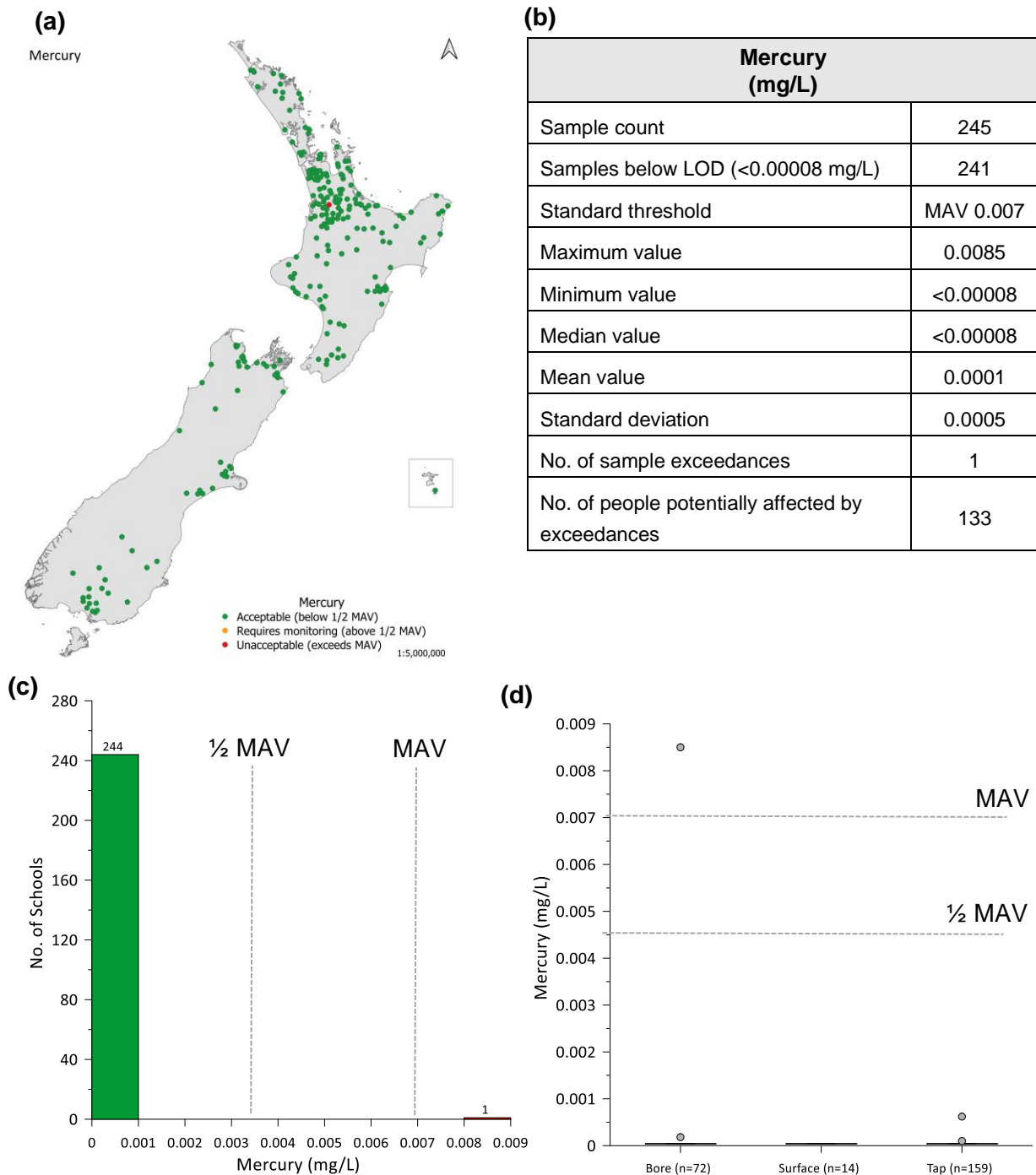


Figure 5.22 Rural school drinking-water mercury, measured in mg/L. (a) Map of sampling site locations classified by New Zealand drinking-water standards. (b) Mercury statistical data across the sites. (c) Mercury concentration histogram distribution. (d) Mercury concentration classed by water-sample type.

Mercury concentrations were rarely detected in school drinking-water samples, with 241 samples below LOD (<0.00008 mg/L). Of the four samples that were detectable, only one sample exceeded the MAV (0.07 mg/L) at 0.085 mg/L. This sample was collected from a bore in the Waikato region.

5.22 Nitrate-N

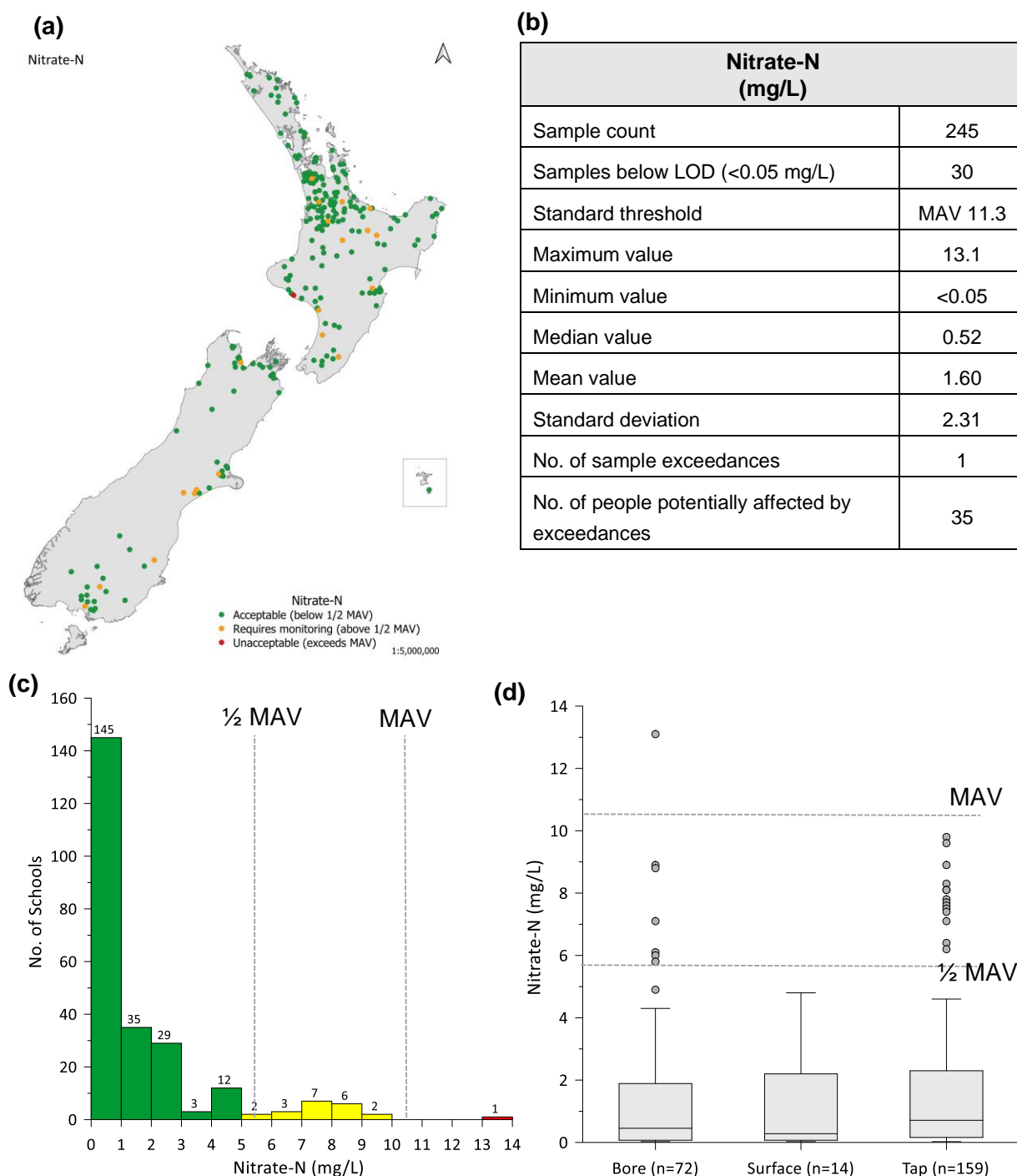


Figure 5.23 Rural school drinking-water nitrate-N, measured in mg/L. (a) Map of sampling site locations classified by New Zealand drinking-water standards. (b) Nitrate-N statistical data across the sites. (c) Nitrate-N concentration histogram distribution. (d) Nitrate-N concentration classed by water-sample type.

Nitrate-N concentrations ranged from below LOD (0.05 mg/L) up to 13.1 mg/L. A single school exceeded the MAV (11.3 mg/L) with a nitrate-N value of 13.1 mg/L. However, 20 schools also had nitrate-N levels between $\frac{1}{2}$ MAV and MAV. Only 30 schools had drinking water below LOD, and the median and mean nitrate-N values were 0.52 and 1.6 mg/L. Mean nitrate-N and inter-quartile ranges across all water types (bore, surface and tap water) were similar, suggesting that nitrates are present across all freshwater sources and not removed by existing water-treatment systems provided in schools.

5.23 Nitrite-N

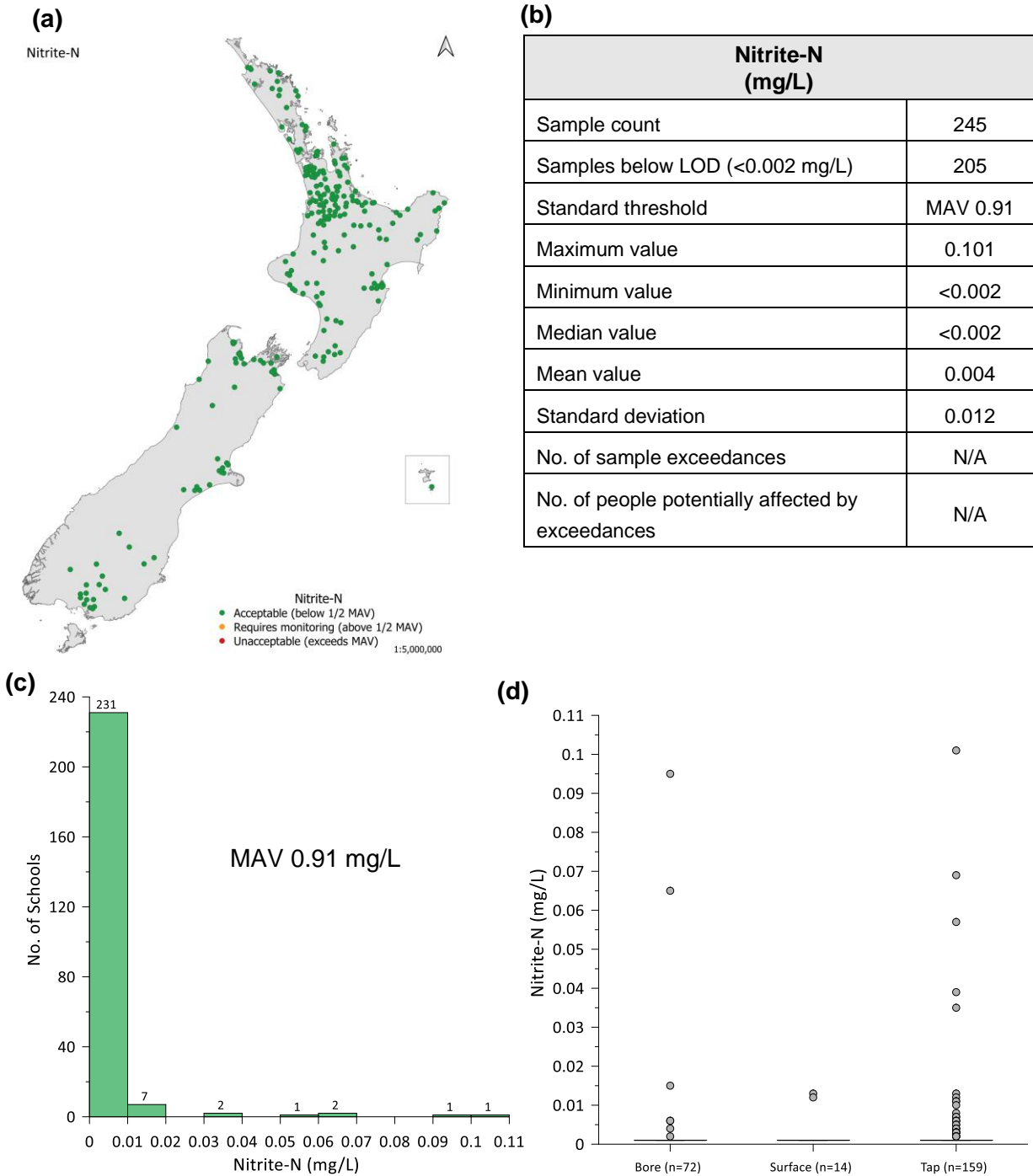


Figure 5.24 Rural school drinking-water nitrite-N, measured in mg/L. (a) Map of sampling site locations classified by New Zealand drinking-water standards. (b) Nitrite-N statistical data across the sites. (c) Nitrite-N concentration histogram distribution. (d) Nitrite-N concentration classed by water-sample type.

Nitrite-N concentrations were measured above LOD (<0.002 mg/L) in only 40 sites, with a maximum value of 0.10 mg/L. All measurable samples were below Nitrite-N MAV limits of 0.91 mg/L. Measurable nitrite-N was found in all water types (bore, surface and tap water), consistent with similar findings for nitrate-N.

5.24 pH

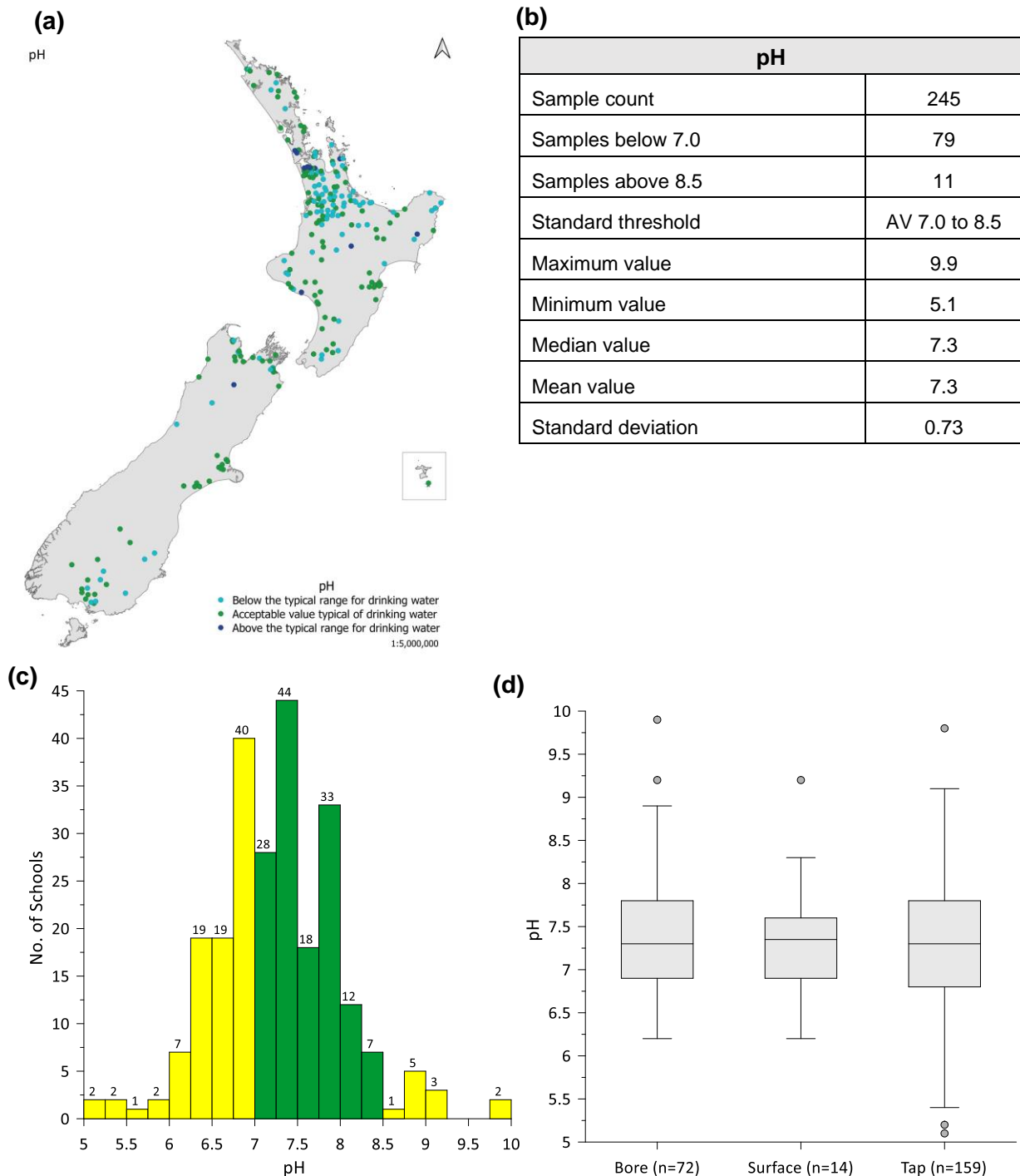


Figure 5.25 Rural school drinking-water pH, measured in pH units. (a) Map of sampling site locations classified by New Zealand drinking-water standards. (b) pH statistical data across the sites. (c) pH concentration histogram distribution. (d) pH concentration classed by water-sample type.

A wide range of pH values were found in drinking water sampled across New Zealand rural schools. The majority (155 samples) had pH values lying between 7.0 and 8.5 and are within the typical aesthetic guideline range for drinking water (Taumata Arowai 2022a). Of the 245 samples, 79 sites had pH values below this range with a minimum pH value of 5.1, and 11 samples had pH values above the range with a maximum pH value of 9.9. Median and mean pH values were 7.3, respectively. While all three water types showed outlier pH values up to 9.9, tap water had a much larger pH range than bore or surface water, and also had pH outliers values below 5.5.

5.25 Potassium

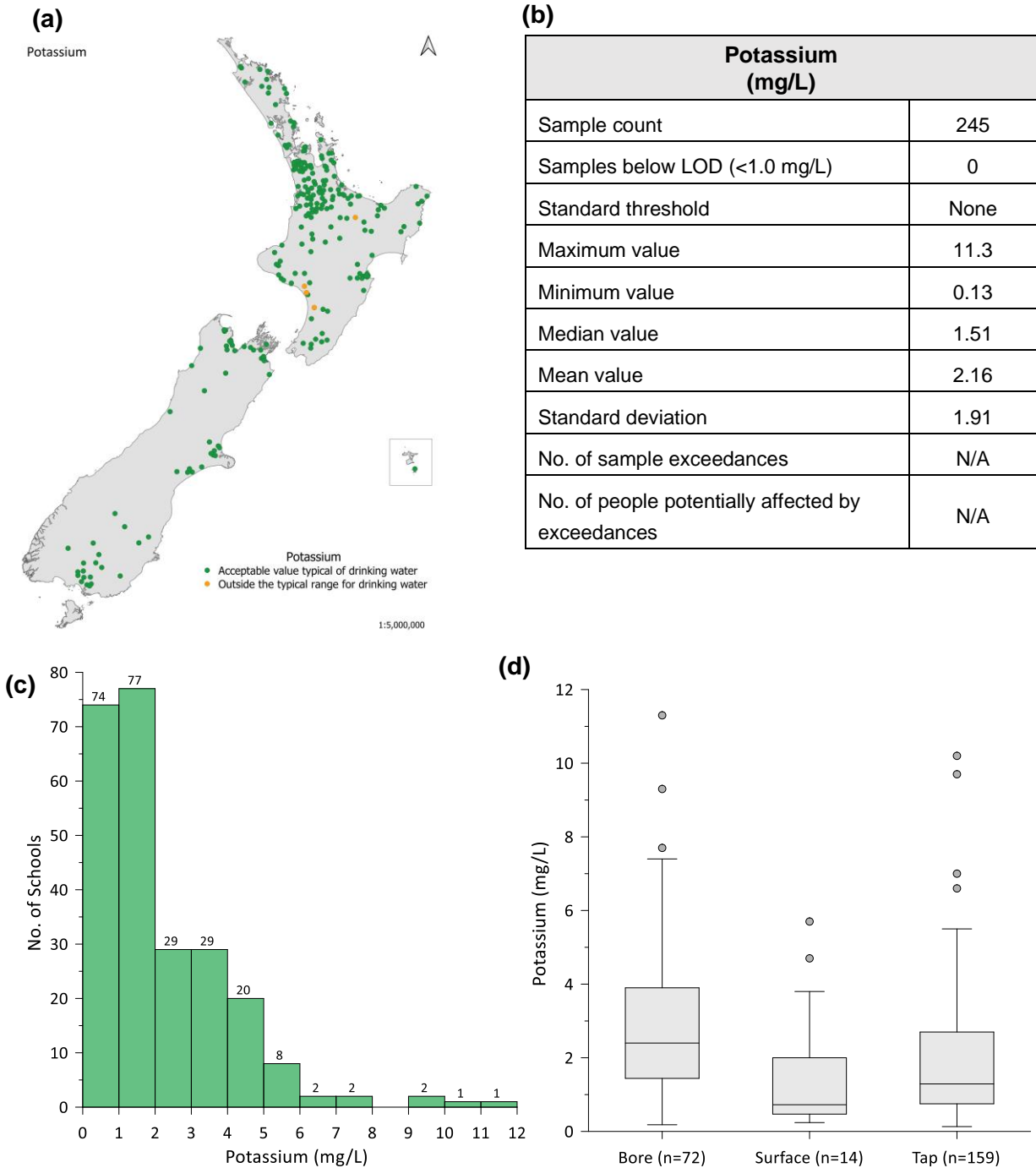


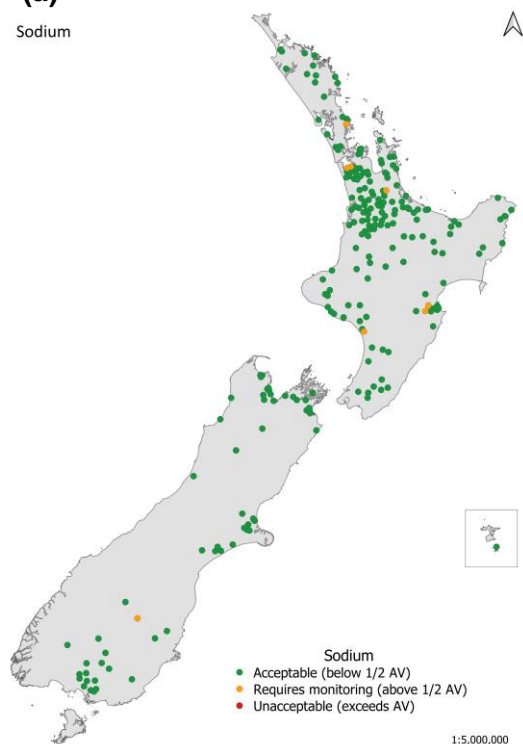
Figure 5.26 Rural school drinking-water potassium, measured in mg/L. (a) Map of sampling site locations classified by New Zealand drinking-water standards. (b) Potassium statistical data across the sites. (c) Potassium concentration histogram distribution. (d) Potassium concentration classed by water-sample type.

Potassium ranged from 0.13 to 11.3 mg/L. While there are no guideline threshold levels set for potassium in drinking water, a recommended range is suggested between 0 and 8 mg/L (World Health Organisation 2010). Outlier potassium values (>8 mg/L) were found in all water-source types. Most samples had potassium levels below 5 mg/L, with a median and mean of 1.51 and 2.16 mg/L, respectively. Potassium is found to have a higher median and wider inter-quartile range in bore water than in surface and tap water. Potassium is usually sourced from minerals in rocks and soil, although potassium permanganate can be used as an oxidant in water treatment, and potassium chloride can even be used for water softening.

5.26 Sodium

(a)

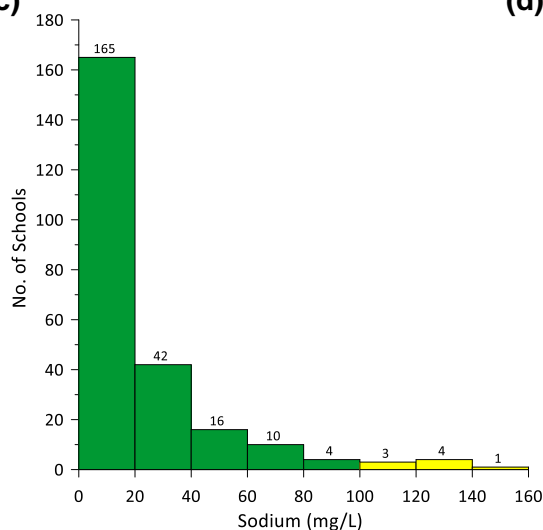
Sodium



(b)

Sodium (mg/L)	
Sample count	245
Samples below LOD (<1.0 mg/L)	0
Standard threshold	AV 200
Maximum value	151
Minimum value	0.80
Median value	12.7
Mean value	22.9
Standard deviation	26.7
No. of sample exceedances	N/A
No. of people potentially affected by exceedances	N/A

(c)



(d)

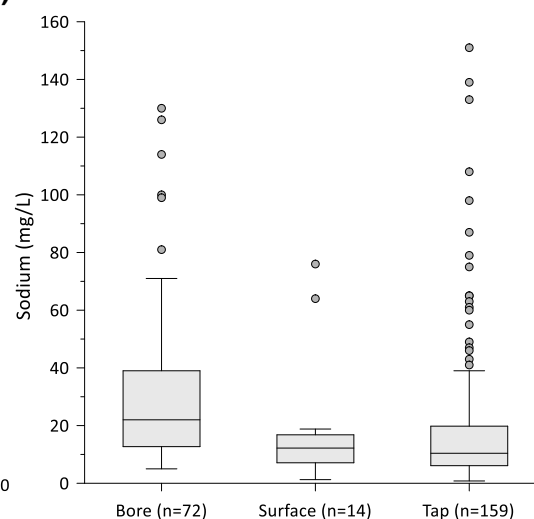


Figure 5.27 Rural school drinking-water sodium, measured in mg/L. (a) Map of sampling site locations classified by New Zealand drinking-water standards. (b) Sodium statistical data across the sites. (c) Sodium concentration histogram distribution. (d) Sodium concentration classed by water-sample type.

Sodium levels ranged from 0.8 to 151.0 mg/L and have AV limits set at 200 mg/L. While there are no AV exceedances, eight samples had sodium values above $\frac{1}{2}$ AV. The highest sodium values (>100 mg/L) were found in both bore and tap water, suggesting that the source may be both geogenic and/or anthropogenic, as it can be introduced through sodium salts in groundwater, i.e. saltwater intrusion or through the water chlorination process or the use of salt as water softeners. Most samples had sodium values below 40 mg/L, with a median of 22.9 mg/L and a mean of 26.6 mg/L. Sodium is found to have a larger inter-quartile range in bore water than in surface and tap water but considerably more outliers in tap water, supporting human-induced excesses.

5.27 Sulphate

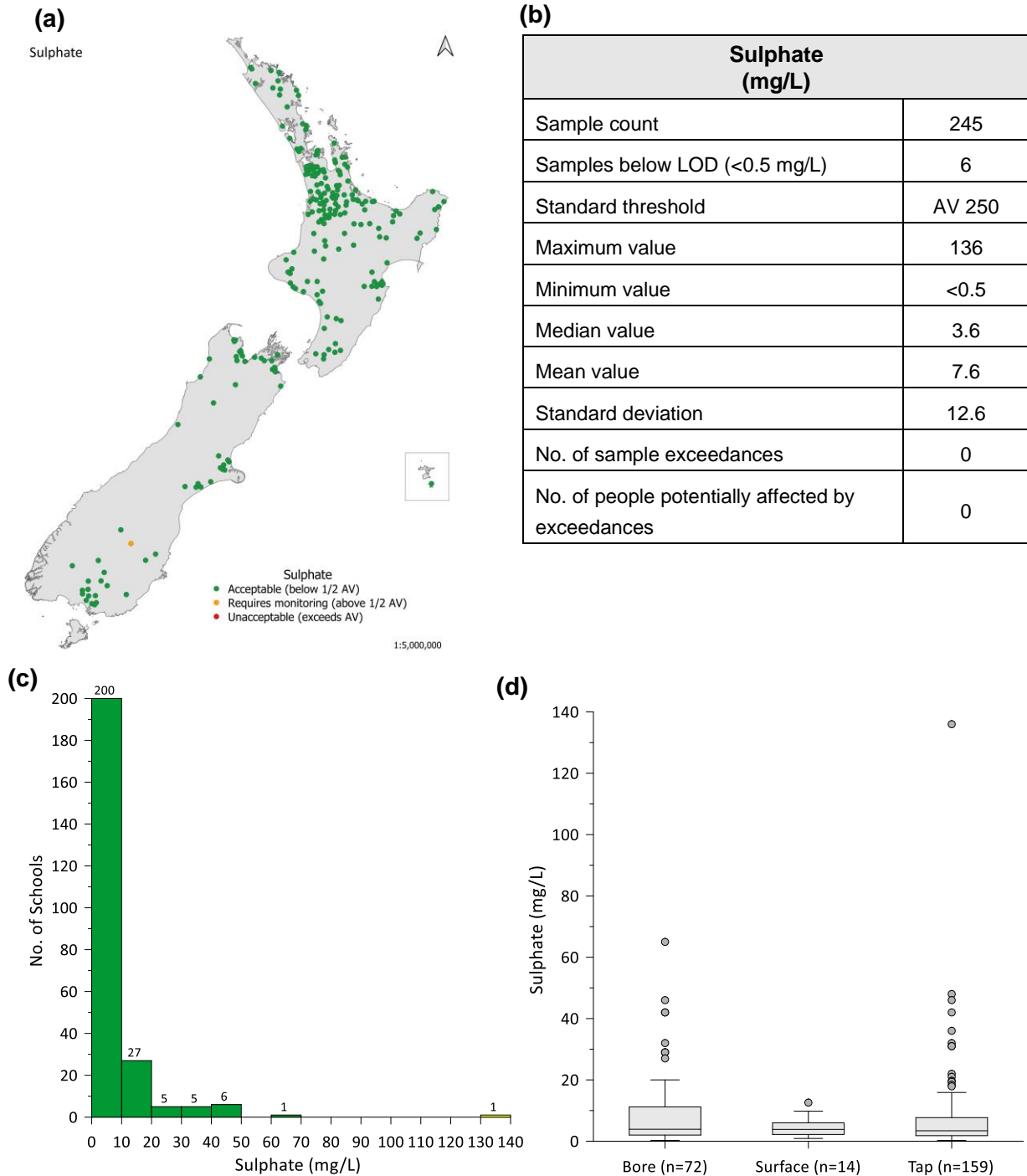


Figure 5.28 Rural school drinking-water sulphate, measured in mg/L. (a) Map of sampling site locations classified by New Zealand drinking-water standards. (b) Sulphate statistical data across the sites. (c) Sulphate concentration histogram distribution. (d) Sulphate concentration classed by water-sample type.

Sulphate levels in drinking water ranged from below LOD (<0.5 mg/L) to 137 mg/L. Aesthetic guideline thresholds are set at 250 mg/L for sulphate in drinking water. Only one tap sample from central Otago exhibited sulphate concentration above ½ AV, which may be indicative of water treatment containing sulphate or sulphites. Most samples had sulphate values below 20 mg/L, with a median of 3.6 mg/L and a mean of 7.6 mg/L. However, six samples tested below LOD of both bore and tap water had outlier sulphate values above 20 mg/L.

5.28 Total Dissolved Solids

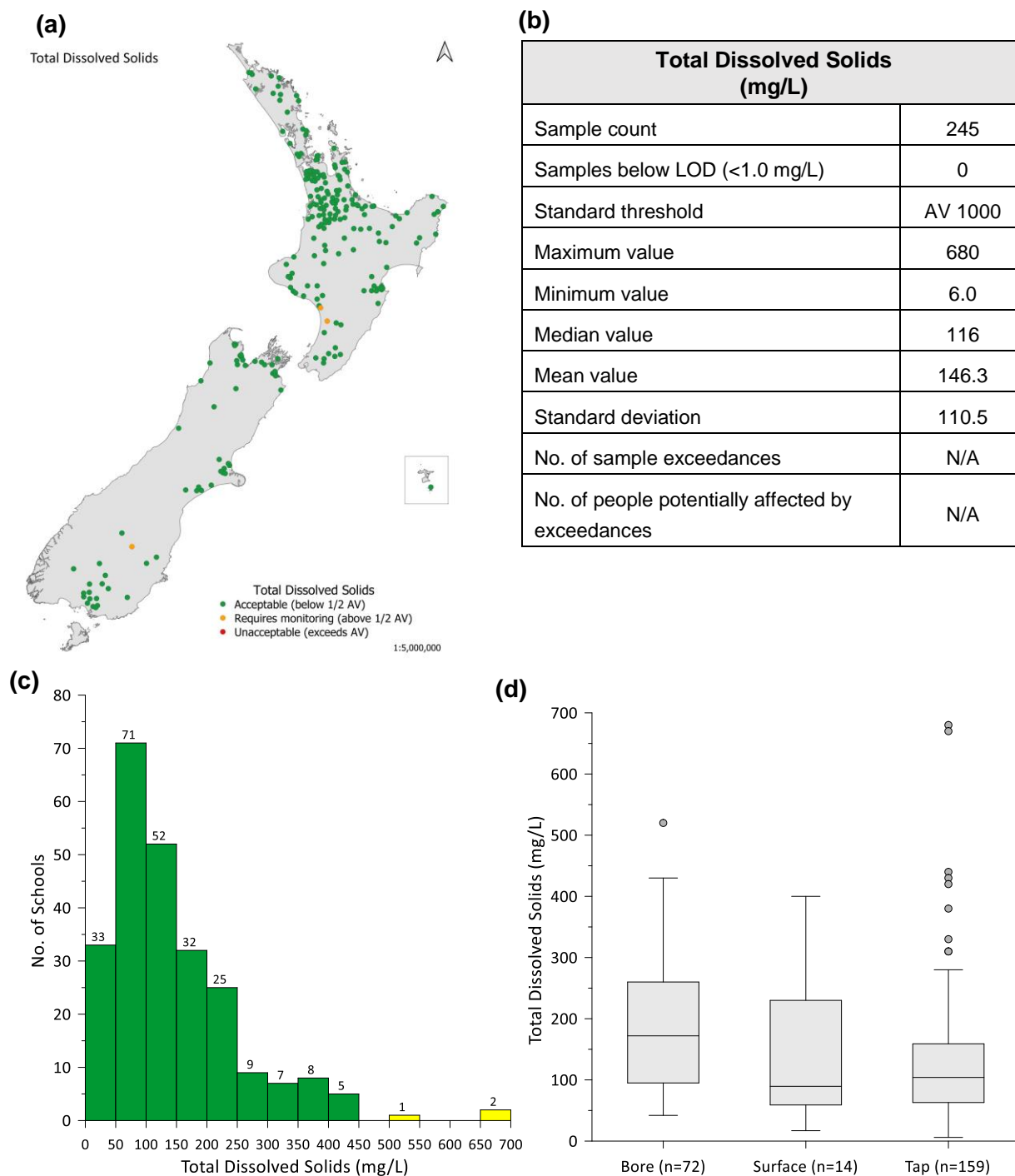


Figure 5.29 Rural school drinking-water total dissolved solids, measured in mg/L. (a) Map of sampling site locations classified by New Zealand drinking-water standards. (b) Total dissolved solids statistical data across the sites. (c) Total dissolved solids concentration histogram distribution. (d) Total dissolved solids concentration classed by water-sample type.

The measured range of total dissolved solids (TDS) in this study was from 6.0 to 680.0 mg/L, and there were no exceedances of the AV (1000 mg/L). Only three samples exceeded $\frac{1}{2}$ AV, although most samples contained <250 mg/L TDS. Higher TDS values (>300 mg/L) were found in all water sources, suggesting that the TDS source is primarily geogenic and not anthropogenic. TDS is found to have a larger inter-quartile range for bore water and surface water than tap water. The median and mean TDS values were 116.0 mg/L and 146.3 mg/L, although bore water had a higher median and mean value than surface and tap water.

5.29 Turbidity

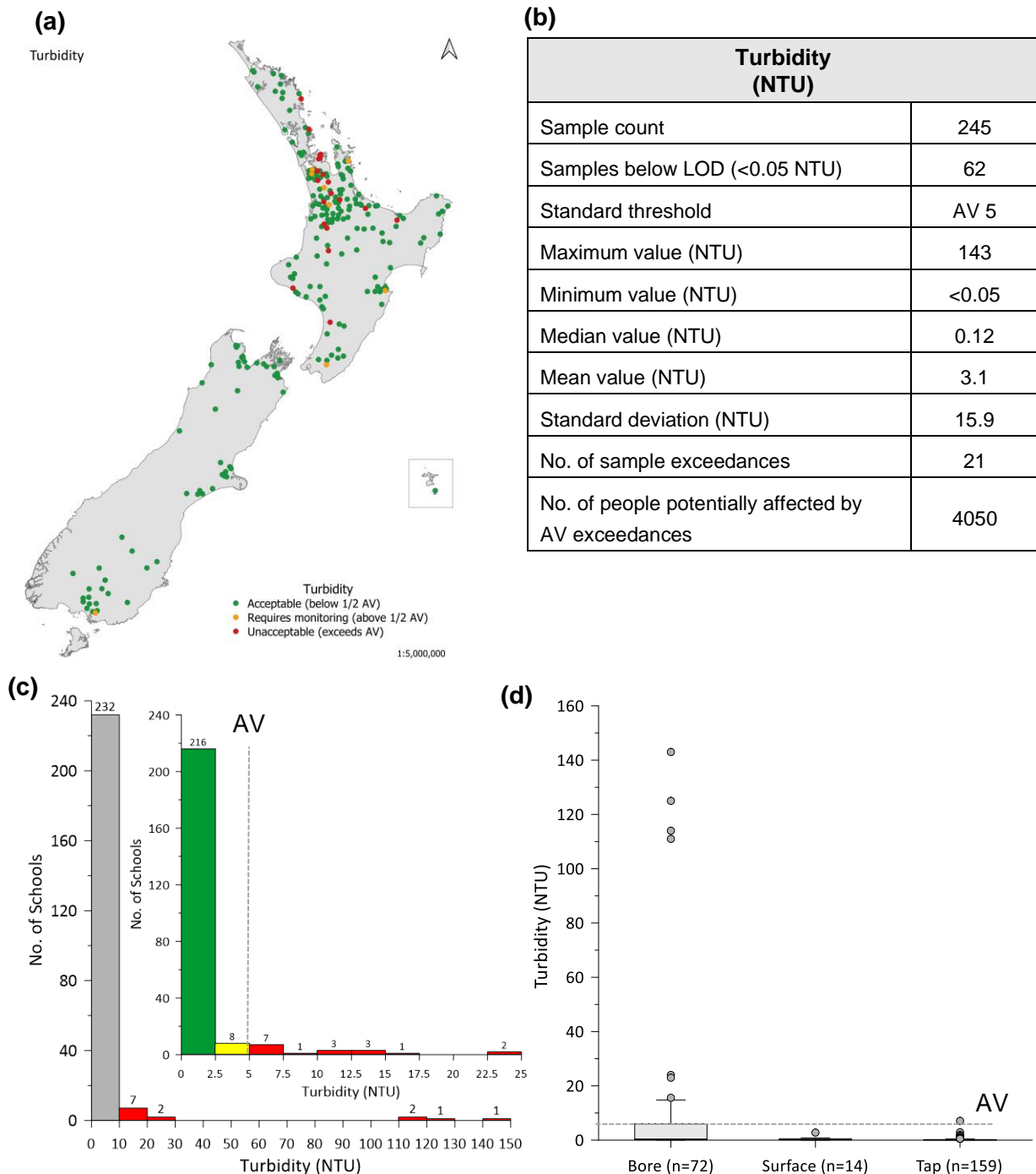


Figure 5.30 Rural school drinking-water turbidity, measured in NTU. (a) Map of sampling site locations classified by New Zealand drinking-water standards. (b) Turbidity statistical data across the sites. (c) Turbidity concentration histogram distribution. (d) Turbidity concentration classed by water-sample type.

Drinking-water turbidity ranged from below LOD (<0.05 NTU) to 143.0 NTU. Aesthetic guideline thresholds are set at 5 NTU, and 21 exceedances of this determinand were identified, primarily in water sampled from bores. Only one sample exceeding AV was recorded from tap water with a turbidity value of 7.1 NTU. Most samples had turbidity values below 2.5 NTU, with 62 samples below LOD, a median of 0.12 NTU and a mean of 3.1 NTU. Turbidity is found to have a larger inter-quartile range and more outliers in bore water that is unfiltered than in surface water and filtered tap water.

5.30 Zinc

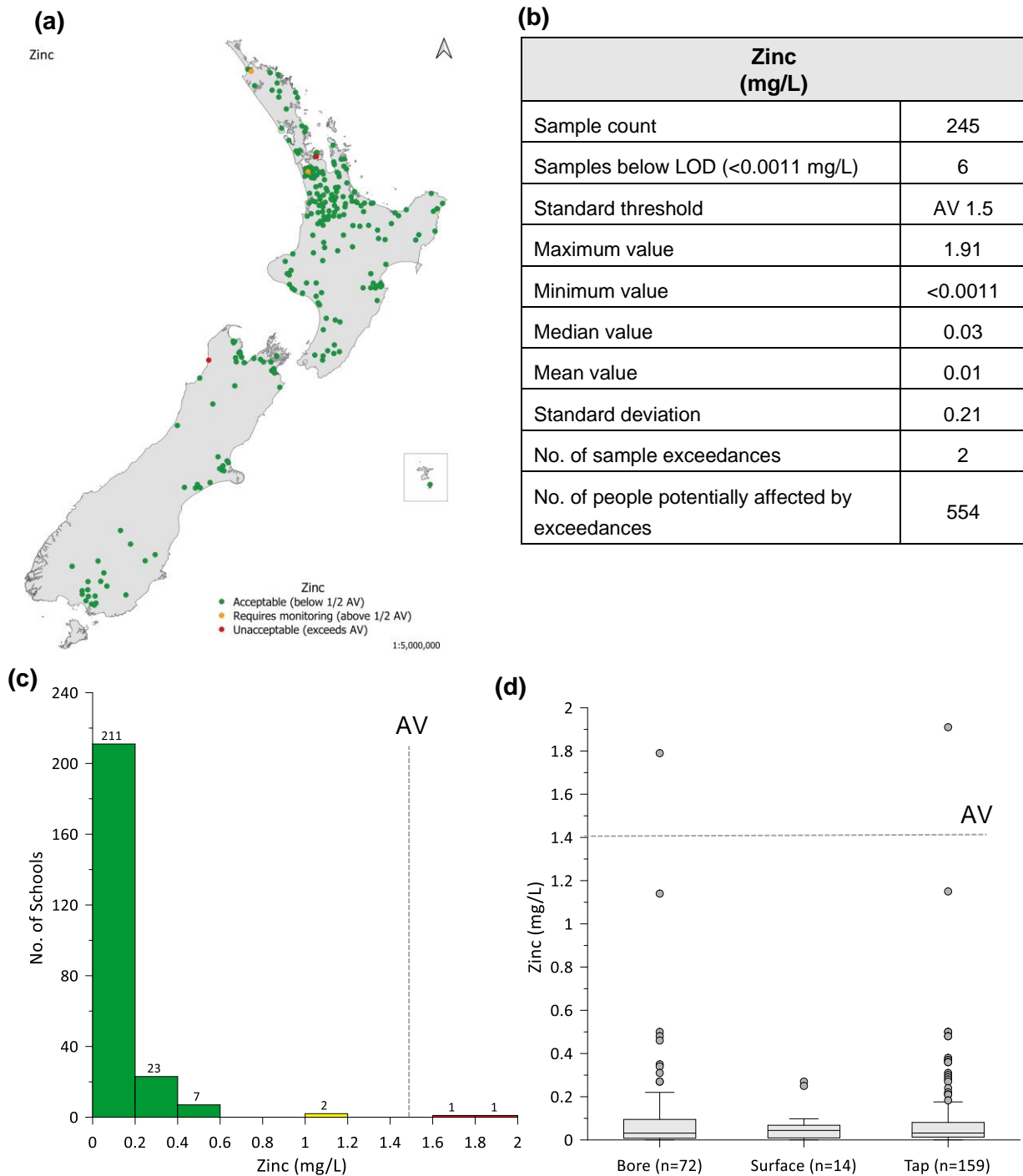


Figure 5.31 Rural school drinking-water zinc, measured in mg/L. (a) Map of sampling site locations classified by New Zealand drinking-water standards. (b) Zinc statistical data across the sites. (c) Zinc concentration histogram distribution. (d) Zinc concentration classed by water-sample type.

Zinc concentrations ranged from below LOD (<0.0011 mg/L) to 1.91 mg/L. Two samples exceeded the AV threshold of 1.5 mg/L set for zinc in drinking water. Six samples were below LOD, and most samples were below 0.4 mg/L, with a median of 0.03 mg/L and a mean of 0.01 mg/L. Higher zinc values (>0.2 mg/L) were found in bore, surface and tap waters, suggesting that zinc may not be removed from water using existing water filtration methods.

6.0 DISCUSSION

6.1 Survey Results

Analysis of the determinands in untreated bore and surface waters from rural regions provides an indication of the prevailing local groundwater conditions at each site, while the tap water gives a clearer overview about drinking-water quality delivered to schools after water treatment. Different geological, geochemical, biological, climate and anthropogenic conditions can influence the attenuation of certain determinands.

- **Major elements and dissolved metals** such as calcium (Ca), chloride (Cl), fluoride (F), iron (Fe), magnesium (Mg), potassium (K), sodium (Na) and zinc (Zn) provide a rapid overview of the water/rock chemistry. These elements provide essential dietary minerals that, within acceptable ranges, are required to support human health.
- **Trace elements**, including toxic heavy metals and metalloids such as arsenic (As), antimony (Sb), boron (B), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), manganese (Mn) and mercury (Hg), adversely affect human health. Their presence indicates local land-use impacts but, in some instances, may be derived from geological, geothermal or soil influences or from plumbosolvency (the ability of water to dissolve metals such as lead or copper from plumbing fittings).
- **Physico-chemical determinands** such as alkalinity, conductivity, free carbon dioxide, hardness, pH, total dissolved solids and turbidity provide insight into water/rock interaction and are influenced by the presence and abundance of other elements found in water.
- **Anthropogenic activity-related contaminants** such as *Escherichia coli*, nitrate-N (NO₃), nitrite-N (NO₂), ammonia (NH₃) and sulphate (SO₄) are key indicators of faecal waste or fertilisers that are known to render drinking-water unsafe or unfit for consumption.

Water naturally contains many elements and constituents that, in small quantities, are essential for human health. However, some determinands are toxic in large quantities, and guidelines have been set by the Ministry of Health (2018; Water Services [NZDWS] Regulations 2022) to describe acceptable threshold levels of these substances in drinking water. The overall range of these determinands found in New Zealand's rural drinking water provides insight into groundwater health and guides the frequency of routine regulatory testing to ensure that drinking-water quality and safety and is maintained to a similar standard as town-supplied drinking water.

6.1.1 Major Elements and Dissolved Metals

Major elements and dissolved metals (Ca, Cl, F, Fe, Mg, K, Na, Zn) are naturally present in geological sediments that are in contact with the groundwater. New Zealand's rural school bore- and surface-source waters are generally within the range of AV guidelines for drinking water apart, from Fe and Zn (Figure 6.1; Appendix 5).

Based on the low levels of Ca, F, Mg and K found in this study, these are not considered to be drinking-water determinands of concern in New Zealand's rural schools. Although Na and Cl levels were not found to exceed any aesthetic value limits, careful attention should be paid by water-supply managers to ensure that correct salt dosages are used in water treatments to ensure that these levels remain low.

Water samples from regions prone to a higher **Fe content should be regularly tested**. Water-treatment systems at schools in iron-rich sites may need more frequent maintenance than regions with lower concentrations. Similarly for schools where high Zn concentrations were measured, treatment should be reviewed.

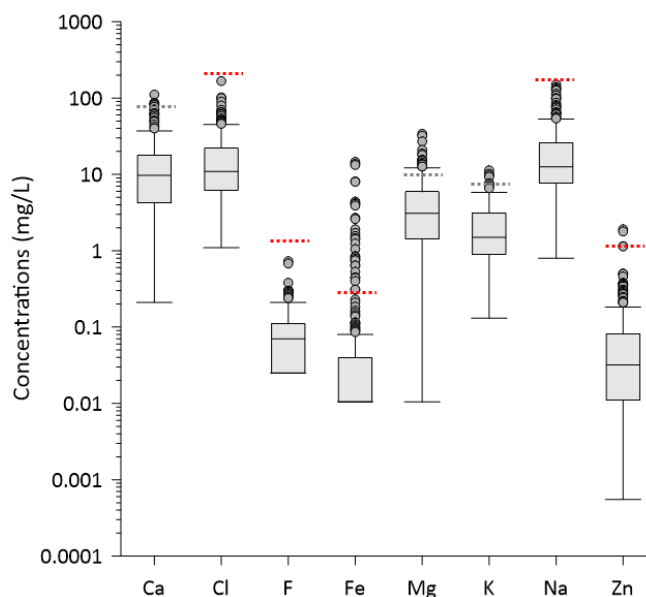


Figure 6.1 Plot of major element determinands showing log[concentrations]. Dashed red lines represent MAV or AV thresholds for drinking water. Dashed grey lines represent typical range limits for drinking water for determinands without MAV or AV thresholds.

6.1.2 Trace Elements

In this study, the elemental concentrations of trace determinands that are of significant public health concern (As, Sb, B, Cd, Cr, Cu, Pb, Mn, Hg) are usually below MAV, apart from As (three MAV exceedances), Pb (five MAV exceedances), Hg (one MAV exceedance) and Mn (two MAV exceedances), (Figure 6.2; Appendix 5). These determinands can be derived from both natural and anthropogenic sources and are difficult to identify without proper laboratory testing.

Given the low levels of Sb, B, Cd, Cr, Cu and Hg measured in this study, these are not considered to be determinands of concern in New Zealand's rural drinking water. Hg is not routinely analysed in drinking-water surveys, so there is little historical information regarding Hg levels in New Zealand's drinking water; this survey has provided valuable baseline information.

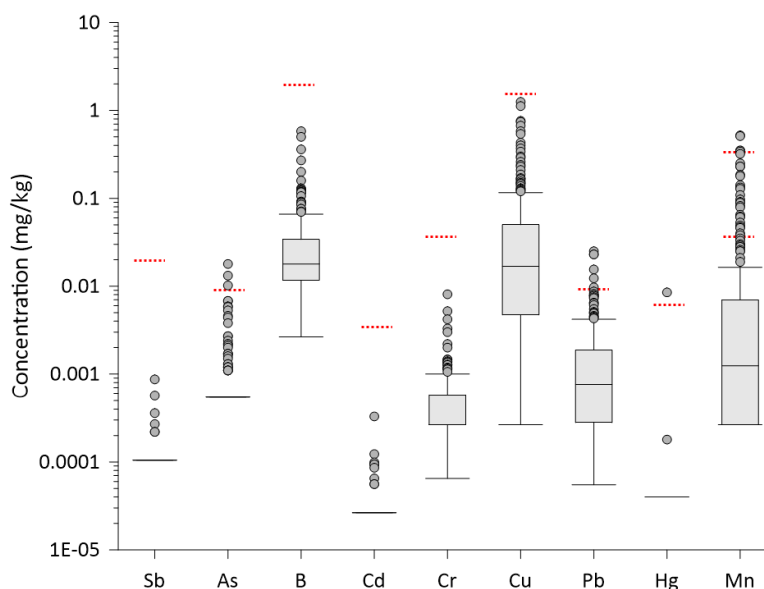


Figure 6.2 Plot of toxic element determinands showing log[concentrations]. Dashed red lines represent MAV or AV thresholds for drinking water. Dashed grey lines represents a typical range for drinking water for determinands without MAV or AV thresholds.

6.1.3 Physico-Chemical Determinands

Alkalinity, conductivity and free carbon dioxide (CO₂) are not governed by health or aesthetic guidelines, although hardness, pH, TDS and turbidity are (Figure 6.3). In this study, most hardness, TDS and turbidity exceedances were found in bore water. However, as bore water is filtered and treated to remove solids before consumption, none of the exceedances are assessed as concerning, assuming that the filtration and treatment systems are regularly maintained and operating effectively.

Measured alkalinity, conductivity, free CO₂ and TDS were within expected ranges for these determinands and not considered to be cause for concern. It should be noted that hard water may shorten the lifespan of some appliances and water-treatment infrastructure due to mineral build-ups, so hardness should be mitigated where necessary with water softeners. A wide range of pH was measured in rural drinking water, indicating a potential requirement for better pH control particularly to address low pH to protect plumbing and water treatment infrastructure and avoid elevated dissolved metal concentrations.

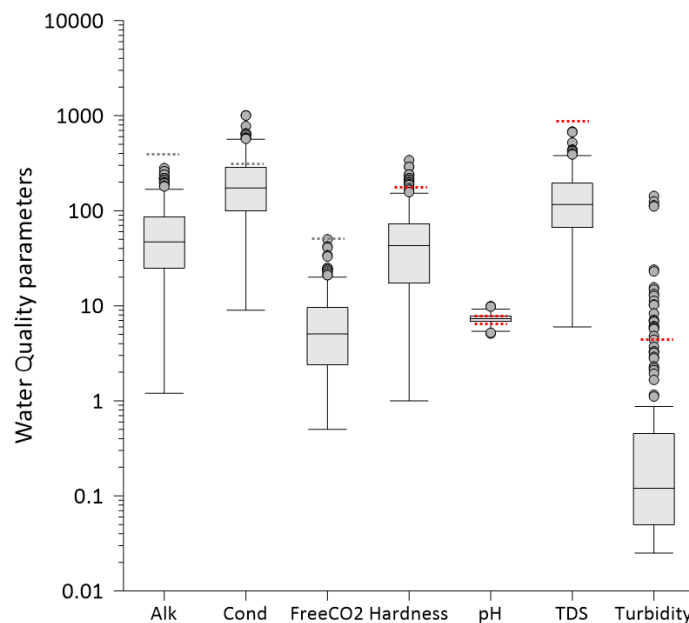


Figure 6.3 Plot of water-quality determinands showing log[concentrations]. Dashed red lines represent MAV or AV thresholds for drinking water. Dashed grey lines represent a typical range for drinking water for determinands without MAV or AV thresholds.

6.1.4 Anthropogenic Activity-Related Contaminants

The anthropogenic contaminants (*E. coli*, NO₃-N, NO₂-N, NH₃, SO₄) tested in this study arise from nutrient or waste sources and are well known to be problematic in New Zealand groundwater.

E. coli was detected in 20 out of 245 water samples in this study (Figure 6.4). While most occurrences were in untreated bore water or surface water that had not yet undergone disinfection treatment, three schools submitted treated tap water with *E. coli* present. In the event of a water-treatment plant failure, including loss of electricity due to a natural hazard event (flooding, earthquake, storm, landslide, etc.), schools with *E. coli* present in their untreated groundwater or surface water would be unable to supply safe potable water if the school was used as a community hub. For schools with persistent or seasonal *E. coli*, the pro-active use of a shock chlorination dosing to reduce the risk of contamination during high-risk periods, i.e. post-holiday shutdown, is recommended.

NO₂-N, NH₃, and SO₄ concentrations were generally measured within the accepted range for drinking water and are not considered to be drinking-water determinands of concern in New Zealand's rural schools. However, nitrate (NO₃-N) trends are somewhat more concerning. While there was only a single exceedance of the NZDWS for NO₃-N concentration, a further 20 school supplies were measured with nitrate levels above ½ MAV. Considering the current available published information on nitrate toxicity (see Section 1.0), nitrate levels should be re-assessed as national guidance evolves. To provide context, most NO₃-N concentrations from town-water supplies are generally reported below 1.0 mg/L (GNS Science [2024]; KM Rogers, pers. comm.). In this survey, 100 school drinking-water NO₃-N concentrations were measured above 1.0 mg/L. It should be noted that nitrate is not removed through existing filtration or UV water treatment processes commonly used by rural schools.

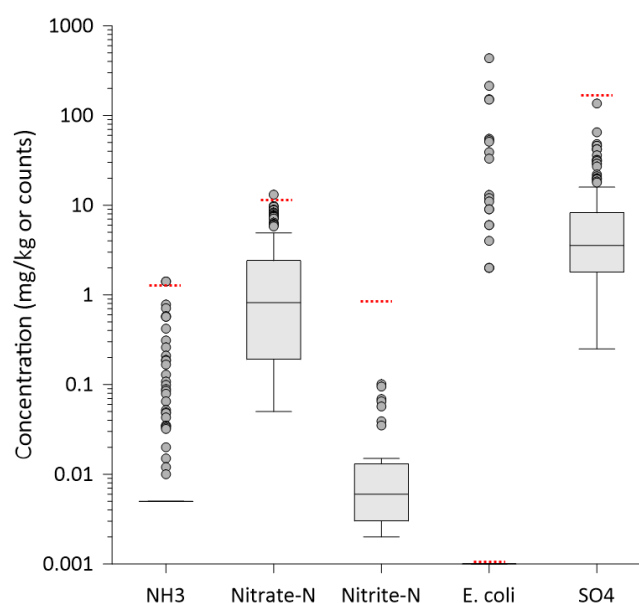


Figure 6.4 Plot of anthropogenic contaminant determinands showing log[concentrations]. Dashed red lines represent MAV or AV thresholds for drinking water. Dashed grey lines represent a typical range for drinking water for determinands without MAV or AV thresholds.

6.1.5 Summary and Prioritising of Determinand Monitoring

This study has identified 12 determinands that have exceeded MAV ($n = 6$) or AV ($n = 6$) in one or more school water supplies, as well as a further six determinands that exceed ½ MAV in this national assessment. These determinands are shown in Table 6.1 and provide a prioritised testing list for school water suppliers of 'at-risk' determinands. Concerningly, all MAV determinands in the list, apart from *E. coli*, are not effectively or completely removed from tap water with filtration and UV water treatment systems, so more effective treatment systems may be required.

Table 6.1 Number of each determinand exceeding maximum acceptable values (MAV), aesthetic values (AV) or ½ MAV guidelines in rural school drinking water.

>MAV	>AV	>½ MAV
<ul style="list-style-type: none"> • Arsenic – 3 • <i>E. coli</i> – 20 • Lead – 5 • Manganese – 2 • Mercury – 1 • Nitrate-N – 1 	<ul style="list-style-type: none"> • Hardness – 12 • Iron – 31 • Manganese – 28 • pH – 90 • Turbidity – 21 • Zinc – 2 	<ul style="list-style-type: none"> • Arsenic – 9 • Copper – 3 • Lead – 19 • Manganese – 10 • Mercury – 1 • Nitrate-N – 21

6.2 Statistical Analysis of Water Quality and Water Type

The range and presence of specific determinands typically associated with bore, spring and tap water were investigated using PLS-DA (Figure 6.5). The centroid (the average measure of a water-source type) of the three water sources (bore, surface and tap water) plotted in different quadrants in the PLS-DA loading plot (Figure 6.5). Bore- and tap-water centroids plotted in opposite quadrants, while the surface-water centroid plotted centrally. Determinands that plot most closely to each water-source centroid are more closely linked to that water source type.

Bore water was shown to positively correlate with K, free CO₂, NH₃, turbidity, *E. coli*, Cd, Mn, Fe, conductivity and Cl. Surface water was positively linked to Hg, Cu, As, Zn and Sb, while tap water correlated more closely with Pb, Cr, NO₃-N, NO₂-N, pH, and F. These positive correlations provide a risk indication of which determinands are most closely linked to specific water-source types and could be used by water regulators and suppliers to identify which determinands should be monitored more closely for each specific water source.

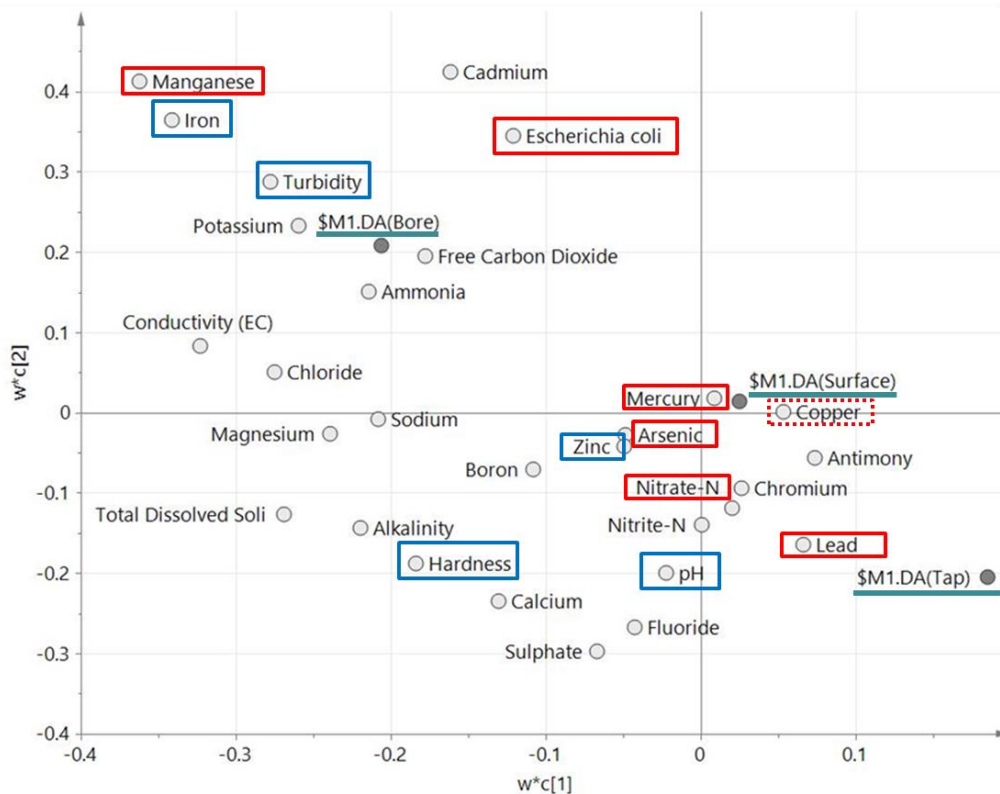


Figure 6.5 PLS-DA loading plot of determinand centroids (light grey circles) and water-type centroids (dark grey circles underlined in dark green). MAV and/or AV determinands with at least one exceedance are enclosed with a red or blue box, respectively. Determinands with concentrations measured between ½ MAV and MAV are enclosed with a red dotted box.

Variable Importance of Projection (VIP) on the x-axis indicates determinands with the most classification influence (ability to separate water sources) (Figure 6.6). When VIP >1, then the determinand makes a significant classification contribution. Determinands with VIP >1 include Mn, Fe, conductivity, turbidity, Cl, TDS, K, Mg, alkalinity and Na, suggesting that these determinands have significantly different concentrations in bore, surface and tap waters. Determinands with higher VIPs have a stronger ability to classify water-source type and are usually located further away from the centre of the loading plot (Figure 6.5), i.e. Mn, Fe and conductivity are clearly correlated with bore water and are more likely to be found in higher concentrations in bore water than in surface water or tap water.

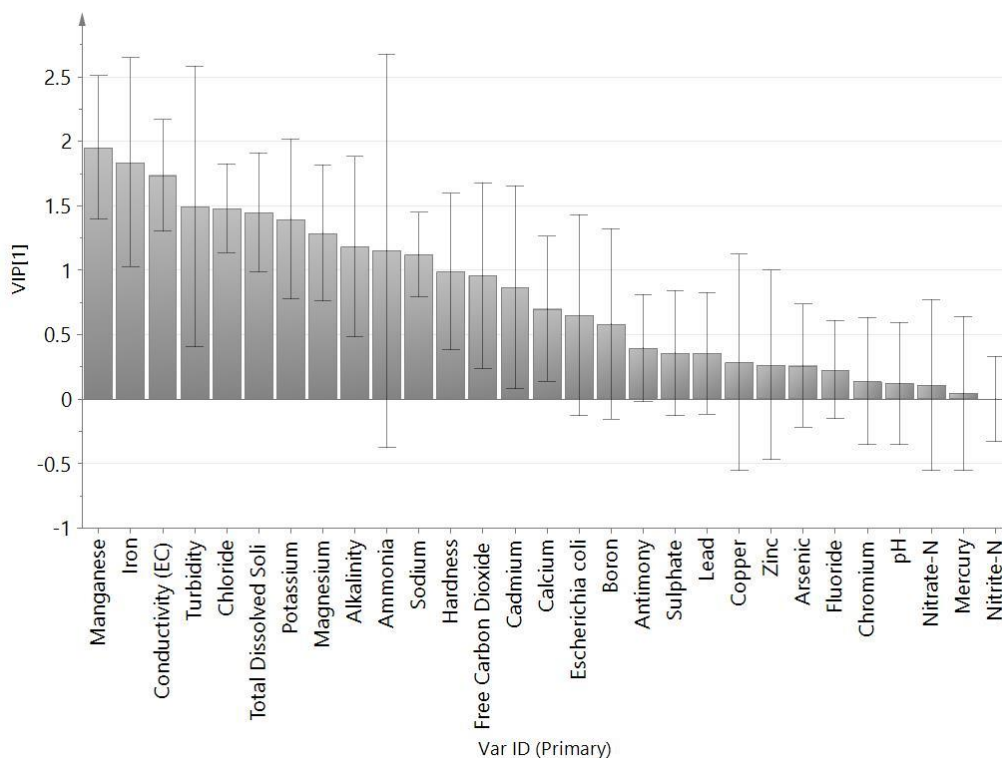


Figure 6.6 Variable of importance projection (VIP) plot of determinands where VIP >1 indicates that the variable significantly contributes to the classification.

6.3 Are Nitrates and *E. coli* Correlated?

Water-quality issues such as elevated nitrates are often regarded as being caused by animal effluent (Rogers et al. 2023); however, in this study, there is a low correlation between NO₃-N levels and *E. coli* (Figure 6.7a) due to the higher mobility of nitrate in groundwater. A few samples with NO₃-N >2 mg/L had *E. coli* counts >1, but most *E. coli* counts >1 had very low NO₃-N values of <0.2 mg/L (Figure 6.7b) or there was no *E. coli* associated with the NO₃-N (Figure 6.7a). Nonetheless, it is possible that elevated nitrate concentrations and *E. coli* counts in a few water sources may be related to leaking septic tanks mixing with the groundwater or *E. coli* contamination from other sources, such as bird faeces washed into water holding tanks, as some drinking water sources use a combination of groundwater mixed with rainwater collected from the roof.

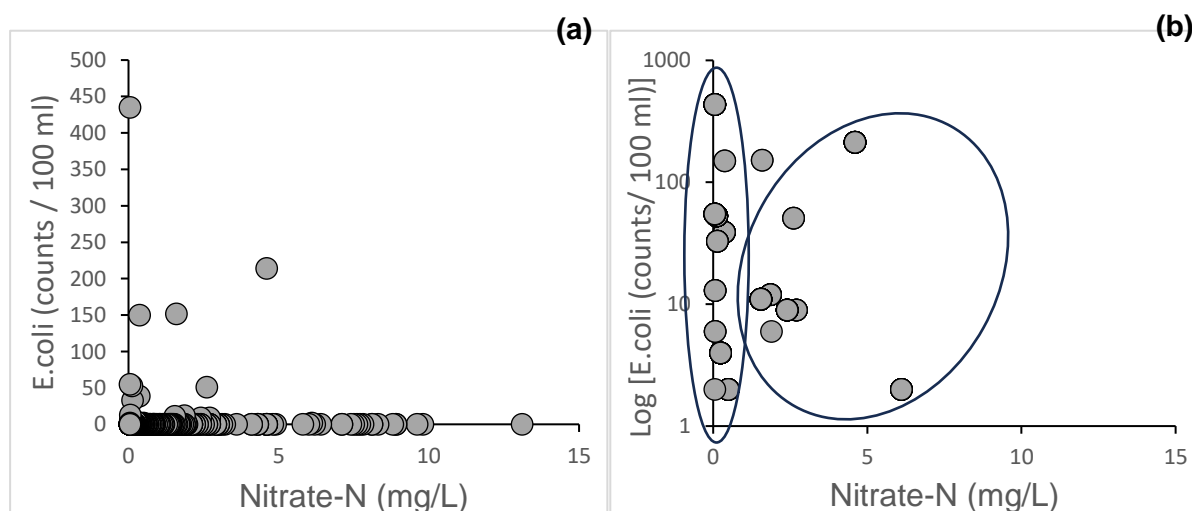


Figure 6.7 Relationship between *E. coli* and nitrates. (a) All nitrate-N and *E. coli* data. (b) Log of *E. coli* counts >1 and associated Nitrate-N values.

6.4 Influence of Low pH on Water Quality

The issue of plumbosolvency poses serious health risks in water reticulation systems with the presence of lead in older water delivery infrastructure. Other metals with a health risk, such as Cu, Cr, Cd, Hg, Sb and Zn, may be present in pipes, tap fittings and associated solders, as well as in some geological and soil settings (either naturally or anthropogenically). Metal solubility is dependent on the acidity of water (pH), temperature and its mineral content.

The effect of pH on all MAV and AV determinand exceedances in this study was assessed to ensure that there was no bias toward water pH affecting determinand exceedances (Table 6.2).

Table 6.2 Assessment of pH effect on determinand maximum acceptable value (MAV) and aesthetic value (AV) exceedance rates. Each determinand shows the number of MAV and AV exceedances below, at and above the pH AV thresholds.

pH	Arsenic	<i>E. coli</i>	Hardness	Iron	Lead	Manganese	Mercury	Nitrate-N	Turbidity	Zinc
<7.0 (n = 79)	0	8	0	10	1	0	1	0	7	0
7.0–8.5 (n = 155)	3	11	12	21	4	2	0	1	14	2
>8.5 (n = 11)	0	1	0	0	0	0	0	0	0	0
Total	3	20	12	31	5	2	1	1	21	2

There were no statistically significant ($p < 0.05$) increases in determinand exceedances found in water with pH <7 and pH >8.5 compared to those seen in water with a pH between 7.0 and 8.5. This result suggests that low or high pH water is not a strong influence on the MAV or AV determinand exceedances found in this study. A comparison between bore and tap water was also undertaken (Appendix 5), and there were no statistically significant ($p < 0.05$) increases in MAV exceedances for determinands found in tap water compared to bore water, apart from Pb, which had four exceedances for tap water and only one exceedance for bore water. This bore exceedance was not related to low pH and is more likely to be due to long pipes and fittings containing lead in the network downstream of a sampling tap.

A similar evaluation was made for determinands above ½ MAV in Table 6.3. Based on the available data, there is no significant influence ($p < 0.05$) of low or high pH water on ½ MAV exceedances. It is notable that the number of MAV, ½ MAV and AV exceedances is proportionally much lower for water with pH >8.5 than for water with pH <7.0 and water with pH between 7.0 and 8.5, most likely due to lower elemental solubility in higher pH water.

Table 6.3 Assessment of pH effect on determinand ½ maximum acceptable value (MAV) exceedance rates. Each determinand shows the number of ½ MAV exceedances below, at and above the pH AV thresholds.

pH	Arsenic	Copper	<i>E. coli</i>	Hardness	Iron	Lead	Manganese	Mercury	Nitrate-N	Turbidity	Zinc
<7.0 (n = 79)	0	2	8	0	11	7	0	1	10	11	0
7.0 to 8.5 (n = 155)	7	1	11	33	26	11	10	0	11	17	4
>8.5 (n = 11)	2	0	1	0	0	1	0	0	0	1	0
Total	9	3	20	33	37	19	10	1	21	29	4

7.0 EVALUATING THE PROCESS OF UNDERTAKING A NATIONAL DRINKING-WATER SURVEY USING A SCHOOL COMMUNITY RESPONSE

The process to undertake a national rural school drinking-water programme required multiple engagement steps with the participating schools. A flowchart outlining the engagement, sampling and reporting process is shown in Figure 7.1.

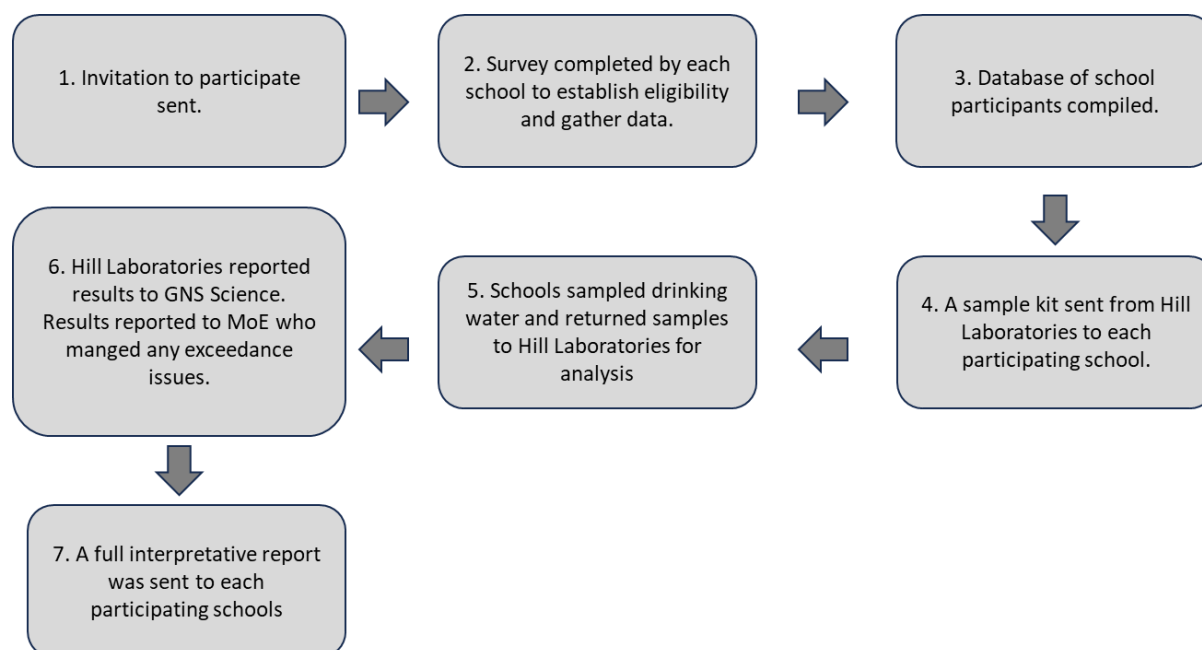


Figure 7.1 Flowchart outlining the process of school engagement, sampling and reporting.

During this study, there were multiple challenges and surprises when engaging with schools. This next section aims to describe these challenges and offer suggestions for regulatory agencies to refine future rural school drinking water testing programmes.

7.1 Engagement with Schools

Initially, the Ministry of Education Water Services Team identified 288 potentially eligible rural schools and provided a detailed contact database to GNS. The first email communication to schools invited participation and emphasised the study's support and cooperation with the Ministry for the Environment and Ministry of Education. This joint approach legitimised the participation request and implied an obligation to participation, rather than it being optional. The invitation email to schools clearly stated that participation would enable schools to comply with the source-water monitoring requirements set by the regulator Taumata Arowai as an incentive.

Participation requests were extended to 288 rural schools that were identified by the Ministry of Education as using groundwater as a primary or secondary drinking water source. There was a 62% positive response rate from these schools after sending the initial email and two further reminder emails. The remaining unresponsive schools needed further follow-up on an individual basis that was relatively time-consuming, as most schools required more than one phone call to make contact and seek agreement to participate. The Ministry of Education's Water Services Team indicates that this is reflective of a broader pattern, where school leaders struggle to execute the broad range of self-governance and management responsibilities placed upon them, with teaching and learning naturally prioritised over other pressures.

Around six schools were identified as not needing to participate, as they had recently moved to rainwater harvesting or town supply, the school had been decommissioned or the school was operating on another site because of Cyclone Gabrielle. A further three schools declined to participate as they already considered themselves Council-compliant, could provide recent testing or opted out of the exercise because they were too busy. Initially, the decline list was larger; however, following scrutiny by the Ministry of Education, only three schools were excused from participation, while the remaining schools received phone calls from the Ministry to emphasise the need to take part, and then elected to take part. Twenty-one schools were identified as not using groundwater so were ineligible, and another 13 schools were not able to be contacted via email or telephone after multiple attempts, so were removed from the participation list. Overall, a total of 245 schools received and returned water sampling kits for analysis.

7.2 Online Survey

In order to gather sufficient data about each school and its ability to take a water sample and understand the analytical results, we generated an online survey with nine questions that all schools had to complete before receiving a sampling package. Completion of the online survey was also a requirement to ensure that consent was obtained regarding the use and storage of collected water-quality data. Sampling kits were not sent to schools that did not respond to the online survey.

The online survey was piloted on 10 schools to see whether there would be any issues to provide responses, but all schools were able to respond without issue, so no further modification was made. Once the survey was finalised, it was sent out to all schools and, in general, most schools were able to respond to the questions. Near the end of the engagement phase, we discovered that a few slow-to-engage schools struggled to answer the survey, as they did not have all the necessary knowledge to answer specific information regarding their water source. In these cases, it was necessary to talk these schools through the survey step by step on the phone to ensure survey completion.

7.3 Shipping of Sample Kits

GNS provided school addresses and contact names to Hill Laboratories, who coordinated the shipping of test kits (Figure 7.2). Each kit was provided with a return courier ticket to cover the sample dispatch costs.



Figure 7.2 Water sampling kit sent by Hill Laboratories to each school.

7.4 Water Sampling

Sample kits were sent out from 1 October until mid-December 2024 (when schools shut down for the Christmas break) and from the end of January 2024 (when schools re-opened) to April 2024. The delay in getting all sample kits sent in 2023 was caused by the slow response of around 80 schools to the survey, as the survey schedule clashed with school-holiday closure and the school-year end and start dates. Finding school staff who were willing to collect untreated water samples directly from the bore- or surface-water source was another major challenge. Some schools have caretakers who are trained to take monthly samples of the untreated water for compliance testing, yet other schools did not. Most administration staff were not confident to sample from the untreated water source, with around 30% of schools stating they did not feel competent to manage their water supply. This is an identified knowledge gap for schools and one that should be addressed. At this point, it was agreed between the Ministry for the Environment, the Ministry of Education and GNS to encourage schools to sample their treated tap water if they could not easily access their untreated water source to ensure a maximum number of participants.

An unanticipated challenge was the practical issue around sample dispatch. Many schools found that they could not get the package to the nearest courier depot, as it was often located in a town some distance away from the school. This barrier was overcome by emailing rural postal tickets to these schools so the local postal service could pick-up the parcel from school reception and ship it to Hill Laboratories.

A key requirement of water testing is to keep samples chilled and shipped to the laboratory within 24 hours to avoid bacterial growth or sample degradation. Many schools were unable to meet this requirement, as postal and courier delays due to remote school locations meant that some samples took more than 24 hours to arrive at the laboratory and the sample contents were above 10°C on arrival. There were 132 samples that were not received within this criterion. Some teachers and administrators raised concerns that this was also an ongoing problem for other monthly water-compliance monitoring undertaken for the Ministry of Education and asked if it could explore a more effective way for schools to ship samples or provide onsite testing of *E. coli*. The Ministry is acutely aware of this issue and is looking to take over water-quality sample collection and transport from schools, although this requires significant additional funding.

A decision was made by the Ministry for the Environment, the Ministry of Education and GNS that water samples should still be accepted by Hill Laboratories for analysis even if the samples exceeded the 24-hour time from collection or did not arrive sufficiently chilled. It was more important for the study to record whether *E. coli* was present or not, rather than the actual count. If the sample had no *E. coli*, then bacteria would be absent in the sample even if the shipping criterion was not met. If *E. coli* was detected by the testing laboratory, an alert would be sent by the Ministry of Education to the school so that further *E. coli* testing could be done under correct testing criteria.

In summary, a key challenge for most rural schools was to collect and ship samples back to the testing laboratory within appropriate timeframes, and then to understand the implications of their results. These factors represent a significant deficiency in the effectiveness of the existing drinking-water testing regime in schools. One improvement opportunity is to centralise and regulate rural school drinking-water testing to improve testing consistency and confidence. This measure would ensure rural drinking-water quality disparity does not increase.

7.5 Reporting of Test Results by the Laboratory

GNS was notified by Hill Laboratories upon sample reception and analytical results provided within 7–10 days of sample reception in .pdf and .csv format. The notification of sample reception included a statement on sample condition (e.g. shipping delays). In turn, GNS regularly shared test results with the Ministry of Education, enabling it to advise schools of any concerns raised from the test results before the schools received their individual report.

7.6 Reporting Back to Schools

Schools received tailored reports that placed their results into context of acceptable (green), requiring monitoring (yellow) or exceeding regulatory standards (red) (Figure 7.3). Feedback was received from several schools that praised the report format for its clarity and information supplied about each determinand and how their results compared to typical values for drinking water.

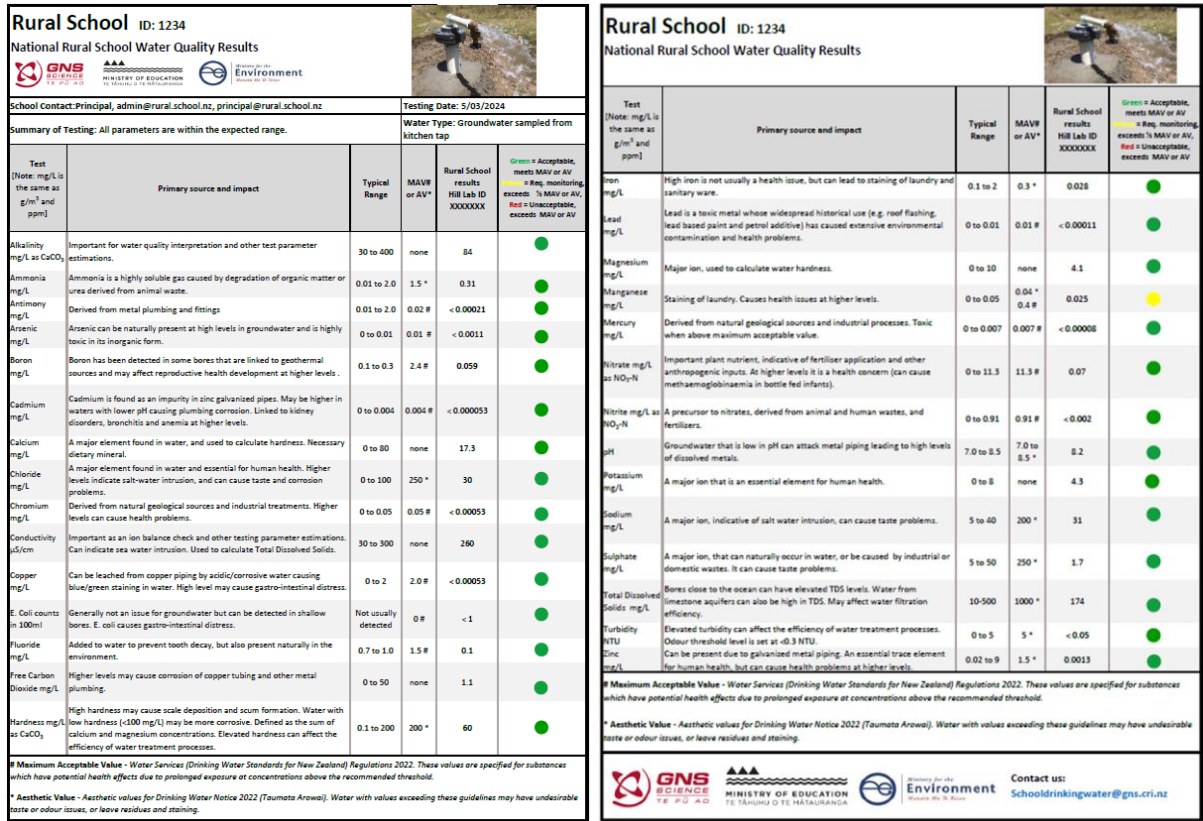


Figure 7.3 Example of personalised school report with drinking water results.

8.0 RECOMMENDATIONS

This national school survey provided a proxy for New Zealand's rural drinking-water and groundwater quality. **Key recommendations for the Ministry for the Environment and Ministry of Education are as follows:**

- *E. coli* was identified as the most at-risk determinand of environmental concern for drinking water in rural New Zealand and, in line with Ministry of Education requirements, should be routinely monitored in groundwater and rural drinking-water supplies.
- Nitrate is the next most at-risk determinand in rural drinking water. Currently the New Zealand nitrate MAV is set at 11.3 mg/L NO₃-N. Much lower nitrate drinking-water thresholds (>0.9 mg/L NO₃-N) have been identified by overseas researchers as posing a higher risk of negative human health impacts (Espejo-Herrera et al. 2016; Schullehner et al. 2018). Significant risks of nitrate toxicity to aquatic organisms in freshwater environments have been proposed by Hickey and Martin (2009) for freshwater containing 1.0 mg/L NO₃-N or more. Daughney et al. (2023) set 80th percentile natural baseline conditions for oxic groundwater at 1.65 mg/L NO₃-N. It is recommended that the Ministry of Education and the Ministry for the Environment keep watch on the ongoing scientific evidence for Nitrate-N thresholds and monitor noticeable concentration changes in drinking water, rather than focusing on the existing MAV threshold, in order to raise awareness about degrading or improving groundwater systems.
- Pb was also identified as a threat for drinking water and should be routinely monitored where older water-delivery infrastructure is present.
- As, Cu, Fe, Hg, Mn and Zn are other elements of concern that require ongoing monitoring if their presence is confirmed in groundwater and rural drinking-water supplies.
- Ministry of Education assistance and funding should continue to be prioritised to investigate, remediate or mitigate determinands in drinking water for any rural school exceeding MAV and/or AV. This may involve updating existing water-treatment systems with improved systems capable of removing any MAV and/or AV determinand exceedance. Installation of these systems can cost between \$1,000 and \$20,000, depending on the water-usage requirements, as well as ongoing maintenance costs.
- Ministry of Education assistance and funding should be directed to ensure that schools continue to monitor water quality of untreated source water and treated tap water for any determinands exceeding ½ MAV.
- The Ministry of Education should consider offering targeted water-management training to self-supplied schools around raising understanding of drinking water supplies, including specific management and maintenance responsibilities, as well as interpretation of water-testing results.

The following recommendations are aimed at the schools who participated in the survey:

- If your school water-supply management staff require further training to become more confident in interpreting water-testing results or to undertake water-supply management activities, a request should be sent to the Water Services Team at the Ministry of Education to identify your needs.
- All schools should ensure that they have an appropriately designed sample tap for taking untreated source water from bores and select treated water sampling taps that will be representative of older water-delivery infrastructure for ongoing monitoring.

For schools with determinands **above MAV**:

- Make provision for an alternative water supply until the treated tap water meets drinking-water standards.
- All schools in this category should re-test both their untreated source water and treated tap water (from the staff room and/or drinking-water fountains) to confirm both pre- and post-treatment determinand levels and confirm the removal efficiency of these determinands by existing water-treatment processes.
- If MAV exceedance is confirmed in treated tap water, schools should advise their school community of the non-compliance.
- Priority is to be given to investigating the cause of determinand exceedance, assessing the risk and implementing effective mitigation or treatment to ensure that treated tap water is safe, as well as ensure effective treatment for all other determinands, e.g. UV disinfection.
- Ongoing three-monthly monitoring of exceedance determinands should occur for both untreated source water and treated tap water.

For schools with determinands **between ½ MAV and MAV**:

- Ongoing three-monthly monitoring of these determinands should occur for untreated source water.

For schools with determinands **above AV**:

- All rural schools with determinands exceeding AV thresholds should undertake regular monitoring, i.e. quarterly, to confirm that the determinand meets or is lower than AV guidelines.
- If appropriate, alternative drinking-water sources should be supplied to any school with determinands exceeding AV that cause aesthetic concerns to staff or students.
- Priority is to be given to investigating the cause of exceedance, assessing the risk and implementing effective mitigation or treatment to ensure that treated tap water is aesthetically pleasing, as well as ensure effective treatment, e.g. UV disinfection.

Finally, the recommendations in this report highlight the need for consistent drinking-water testing for all rural schools as required under the Water Services Act 2021, including:

- Quarterly testing of all determinands exceeding ½ MAV or AV levels in both untreated source water and treated tap water at **all schools supplying their own drinking water** to ensure water-treatment effectiveness.
- A full Routine Water Profile run on **all rural school untreated water sources every three years** to monitor for contaminant changes in groundwater or surface water.

This routine testing requirement will allow the Water Services Team at the Ministry of Education to identify subtle or significant infrastructure issues or groundwater-quality change over time due to climate and changing land-use activities in the surrounding aquifer recharge catchment.

9.0 CONCLUSIONS

The Ministry for the Environment and the Ministry of Education commissioned GNS to undertake, for the first time, a national drinking-water-quality survey of New Zealand rural schools to better understand rural water-quality issues and identify trends and future risks that may affect small rural water suppliers and private bore owners who use groundwater or surface water as their drinking-water source.

Untreated bore and surface water, or treated tap water, was sampled at 245 rural schools by school staff and tested for 29 determinands. The study identified 30 MAV and 48 AV exceedances in rural school drinking-water determinands at 64⁵ schools (26% of schools in this study were affected, excluding pH consisting of 90 schools). Five determinands ranged between ½ MAV and MAV from 42 schools (17% of schools in the study).

There were no exceedances or out-of-range values for alkalinity, B, Cd, Ca, Cl, Cr, conductivity, F, Free CO₂, K, Mg, Na, NH₃, NO₂-N, Sb, SO₄ or TDS. Exceedances for MAV determinands were recorded for *E. coli* (20 schools), Pb (5 schools), As (3 schools), Mn (2 schools), Hg (1 school) and NO₃-N (1 school). These exceedances occurred in both untreated source water and treated tap water with eight recorded exceedances in treated drinking water (Pb, 4 schools; *E. coli*, 3 schools; As, 1 school). One hundred and eighty-four AV exceedances were found in both untreated source water and treated tap water; pH (90 schools) Fe (31 schools), Mn (28 schools), turbidity (21 schools), hardness (12 schools) and Zn (2 schools). However, treated tap water still showed 75 AV exceedances (pH, 58 schools; Mn, 6 schools; hardness, 6 schools; Fe, 3 schools; turbidity, 1 school; Zn, 1 school).

Apart from pH, most MAV and AV water-quality issues were in North Island rural school drinking water. Only eight MAV and AV determinand exceedances (excluding pH) were found in South Island rural schools (hardness, 2 schools; *E. coli*, 2 schools; Fe, 1 school; Pb, 2 schools; Zn, 1 school). Although 90 schools exhibited pH outside the recommended AV range, there were no geographical trends for low or high pH, and a statistical analysis was inconclusive in linking risk of determinand exceedance to low pH (<7.0).

The absence and presence of specific determinands in untreated and treated rural drinking water provides both reassurance and concern for future monitoring requirements. As, *E. coli*, Pb, Mn, Hg and NO₃-N were identified as key at-risk determinants that should be routinely monitored in rural schools due to higher public health risk concerns. Hardness, Fe, Mn, pH, turbidity and Zn are also identified as key aesthetic indicators that require routine monitoring in school drinking water, as, at higher concentrations (or at lower pH levels), they not only affect taste and odour but may interfere with water filtration efficiency.

While many schools are routinely testing treated drinking water for *E. coli* and Total Coliforms on a monthly basis, there is scope to expand testing requirements for at-risk determinands identified in this report and to centralise rural school water testing to ensure that all schools and their test results are captured in a national database. The implementation of a coordinated testing system would ensure that the 'hard-to-contact' schools could be better supported by the Ministry of Education. Furthermore, water-supply management courses could be made available to school staff who manage systems that have had MAV or AV exceedances.

5 Several schools had multiple exceedances.

There is an expectation that school drinking water is fit for purpose and meets New Zealand's Drinking Water Standards, whether it is supplied to an urban or rural school. The reliance on rural schools as community hubs for local residents cannot be under-estimated. Community events are often held at rural schools, during which pressure on school water supplies can increase significantly. There is an expectation that the supplied water is potable and water-delivery infrastructure is robust.

Moreover, in emergency situations such as flood, earthquake, drought, or where the treatment system fails due to a power cut or lack of general maintenance, regular testing of at-risk determinands provides important information on whether the untreated source water could be safely used. It also raises questions around the need for school water-quality disclosure when sharing school facilities with community groups and other users.

Many rural schools in New Zealand have existing water-treatment systems to remove unwanted solids or particles (cartridge filtration) and bacteria (UV treatment or chlorination) from drinking water prior to consumption. Furthermore, while filtration, UV or chlorination treatment of water removes particles and makes it microbiologically safe, these water-treatment systems also improve drinking-water aesthetic values, such as taste or odour and appearance. However, these treatments do not remove dissolved contaminants such as nitrates, nitrites or dissolved trace elements (such as metals, metalloids) or organic compounds.

The Ministry of Education's approach to managing water supplies in schools is to direct investment where evidence identifies a need to mitigate risk and improve outcomes for schools. Results from this study identify drinking-water trends across rural New Zealand and provide guidance for the Ministry of Education Water Services Team, as well as other drinking water regulators and suppliers, about key priorities for mitigating water-quality risks for localised health and societal impacts. Through water-treatment upgrades and implementation of mandatory testing for specific at-risk determinands, it is expected that all rural school drinking-water supplies could attain similar water-supply standards to those achieved in urban supplies and so minimise current drinking-water disparities.

In summary, the biggest challenge for most rural schools is to collect and ship samples to the testing laboratory and then understand the implications of their results. This report highlights that *E. coli*, lead, arsenic and nitrate-N are the biggest threats to rural drinking water quality in New Zealand. Finally, this report identifies an opportunity for rural school drinking-water testing to be centralised and regulated to inform effective treatment and risk mitigation and so ensure that rural drinking-water quality disparity does not increase.

10.0 ACKNOWLEDGEMENTS

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APPENDICES

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APPENDIX 1 SCHOOL QUESTIONNAIRE

National School Drinking Water Survey

Kia ora,

Your school is invited to be part of a National School Drinking Water Survey funded by Ministry for the Environment and Ministry of Education. This study is the first national study to evaluate and compare the quality of rural drinking water from groundwater or surface water sources across New Zealand schools.

Your source water (before treatment) will be tested for 28 different water quality parameters free of charge to ensure your drinking water meets the New Zealand drinking water standards. The results from the testing will be shared with you and can be submitted to Taumata Arowai to comply with your school's 3-yearly compliance testing requirements. All results will be help groundwater scientists to build a picture of rural school water quality and identify any potential issues across New Zealand.

Before we can send your school a test kit, we require some information to help us better understand your school's water source. We would appreciate you responding within 1 week of receiving this questionnaire (or specify date). All test kits and sampling instructions will be sent to your school in the first week of Term 4 (9th October onwards).

Please provide:

School name

School ID number

School address

Respondent Name, email, telephone

Source water location (address or grid reference of source)

1. Where is your school water supplied from; (please tick all that applies)

Town Supply Groundwater bore Spring Rainwater tank Other _____ Unsure

2. If your school water supply comes from a bore, what is the bore depth in meters?

3. What is the maximum number of people who may use this water for drinking purposes?

0 less than 25 26-100 101-500 more than 500

4. When was the source water for your drinking water supply last tested?

5. Do you know which analytes were tested? If YES, could you upload a copy of your last test results?

6. Do you know how to interpret your drinking water test reports to understand your water quality? Yes No Unsure

7. Are you comfortable managing your school's water supply?

Yes No Not sure



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National School Drinking Water Survey

8. Is your school used as a Civil Defence evacuation centre or do you host large community gatherings from time to time, where people drink the existing water supply?

Yes No Unsure Please list: _____

9. How resilient is your water supply under extreme events such as floods, storms, drought, earthquakes, tsunami, landslides etc?

Under threat of _____ Slight risk of _____ No risk of any extreme event

Finally are you able to supply a photo of your school and the water source for reporting purposes.

In order to take part in the national survey, is there someone who can collect water directly from your water source (bore or spring) into sample bottles following clear written instructions, or would you need assistance?



APPENDIX 2 SAMPLE INSTRUCTIONS FOR SCHOOLS

National School Drinking Water Survey

Routine Water Testing and E. coli

Sampling Guide for Schools

Kia ora, and thank you for participating in the National Rural School Drinking Water study led by GNS Science, Ministry of Education and Ministry for the Environment.

Your groundwater or spring water sample is important to this study and these guidelines will provide you with the necessary information to collect and return your water sample to the laboratory for testing.

Your drinking water (sampled before treatment) will be tested (free of charge) for 28 different water quality parameters, to ensure it meets acceptable drinking water standards. The results from the testing will be reported directly back to you and the results aggregated with other schools to understand water quality variability and potential issues across Aotearoa, New Zealand.

In this pack you will find three bottles for sampling your water, sampling instructions and an analysis request form. Please ensure that you read and carefully follow the instructions before filling each bottle. Complete the analysis request form with your school's details and your **Sample Name** (e.g. your school name and school ID), **Sample Date/Time**, **Sample Type** (groundwater or spring sample) and send the sample back as described in the instructions.

We understand that there may be some schools that can't get their samples to a laboratory within 24 hours of sampling. You can safely store the samples in a fridge for a few days until you can organise shipping. Your samples will still be analysed, and results reported back to you.

If you haven't yet emailed a photo of your water source and school, we would be grateful to receive it, so we can provide you with a more individualised report that you can share with your school community. Please send any photos (jpg's) to schooldrinkingwater@gns.cri.nz as soon as possible.

Thanks again for your time to participate and we look forward to sharing your data with you soon.

Ngā mihi nui

Karyne

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Samples for routine water testing and E. coli analysis should be received:

- less than 24 hours from the sample being taken*
- at less than 10°C or less than the source water temperature*
- in a dark container, such as a chilly bin.

Please note: If this is not possible, your sample will still be analysed.

To achieve this, please follow these steps:

	<p>Freeze the gel pack sent with your sampling kit in a freezer overnight.</p>
	<p>Plan delivery</p> <ul style="list-style-type: none"> • If possible, please try to organize sample shipment to arrive at the lab within 24 hours using an overnight courier. If the sample is to arrive on the same day, please sample in the early morning. • If couriating the sample overnight, take the sample in the early afternoon. • If sending a sample on Friday, find out first if the courier delivers on a Saturday. <p>We recommend using New Zealand Couriers - 0800 800 841.</p>
	<p>Collect samples</p> <ul style="list-style-type: none"> • Find the bore tap or source water. If using a bore, run the untreated water from the bore for 3-5 min to avoid sampling water that has been sitting in the bore for some time. <p>The 400mL sterile container for microbiological samples requires special handling – please refer to the instructions over the page for taking the sample.</p> <ul style="list-style-type: none"> • Fill the 500mL unpreserved container, leaving no air gap. • Fill the 100mL Nitric acid preserved container, taking care not to lose any of the acid. (NOTE: NITRIC ACID IS VERY CORROSIVE – CARE IS REQUIRED) <p>Note: Please make sure the DATE and TIME SAMPLED are written on the sample containers! **</p>
	<p>Refrigerate and complete submission form</p> <ul style="list-style-type: none"> • Refrigerate the samples for 1hr, but DO NOT FREEZE! • Complete the supplied submission form with your details and the sample details (including date and time sampled).
	<p>Pack and send</p> <ul style="list-style-type: none"> • Place the frozen gel pack in the chilly bin. • Place the chilled samples above them using the supplied bubble-wrap (or bubble-wrapped ice packs) to keep the samples from direct contact with the gel pack. • Put the completed submission form into the supplied plastic bag, on top of the samples.




National School Drinking Water Survey

	<ul style="list-style-type: none"> Secure the lid of the chilly bin tightly with tape. Attach the supplied address label and pre-paid courier ticket to the top of the chilly bin. <p>Ensure the samples are delivered to Hill Laboratories or the courier company in good time so testing can be started at the laboratory within the 24hr time frame.</p>
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*Note: If samples do not meet time and temperature criteria, Hill Laboratories will proceed with the testing, but a comment will be added to the report saying that Hill Laboratories cannot endorse results for the samples as they do not meet regulatory or analytical requirements.

**Note: If the time and date sampled is not provided, Hill Laboratories cannot know if the time requirement has been met. A comment will be added to the report saying that Hill Laboratories cannot endorse results for the samples as they do not meet regulatory or analytical requirements.

Collecting water samples for E. coli

	<p>Collecting the sample</p> <ul style="list-style-type: none"> Use the sterile container provided. Do not rinse the container before taking the sample. Do not touch the insides of the sterile container or inside the lid. Fill the container to within 1 cm of the top.
	<p>Wells and bores</p> <ul style="list-style-type: none"> Operate the mechanical pump for at least 3-5 minutes before sample collection.
	<p>Rivers, streams and lakes</p> <ul style="list-style-type: none"> Hold the <i>microbiological sample bottle</i> for E.coli near its base and plunge it, neck downwards below the surface. If there is no current, push the bottle forward horizontally away from the hand.

Please send your samples to:

<p>Hill Laboratories Hamilton</p>	<p>Hill Laboratories Christchurch</p>
<p>28 Duke Street, Frankton Hamilton 3204 0508 HILL LAB (0508 44 555 22) env.csm@hill-labs.co.nz</p>	<p>101 Waterloo Road, Hornby Christchurch 8042 0508 HILL LAB (0508 44 555 22) env.csm@hill-labs.co.nz</p>



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APPENDIX 3 ANALYTICAL METHODS

Determinand	Method Used	Detection Limit
Alkalinity	Titration to pH 4.5 (M-alkalinity), auto-titrator. APHA 2320 B (modified for Alkalinity <20): Online Edition.	1.0 g/m ³ as CaCO ₃
Ammonia-N	Phenol/hypochlorite colourimetry. Flow injection analyser. (NH ₄ -N = NH ₄ ⁺ -N + NH ₃ -N). APHA 4500-NH ₃ H (modified): Online Edition.	0.010 g/m ³
Antimony	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B: Online Edition / US EPA 200.8.	0.00021 g/m ³
Arsenic	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B: Online Edition / US EPA 200.8.	0.0011 g/m ³
Boron	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B: Online Edition / US EPA 200.8.	0.0053 g/m ³
Cadmium	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B: Online Edition / US EPA 200.8.	0.000053 g/m ³
Calcium	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B: Online Edition / US EPA 200.8.	0.053 g/m ³
Chloride	Filtered sample. Ion Chromatography. APHA 4110 B (modified): Online Edition.	0.5 g/m ³
Chromium	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B: Online Edition / US EPA 200.8.	0.00053 g/m ³
Conductivity	Conductivity meter, 25°C. APHA 2510 B: Online Edition.	1 µS/cm
Copper	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B: Online Edition / US EPA 200.8.	0.00053 g/m ³
Escherichia coli	MPN count using Colilert (Incubated at 35°C for 24 hours) or Colilert 18 (Incubated at 35°C for 18 hours). APHA 9223 B: Online Edition.	1 MPN / 100 mL
Fluoride	Direct measurement, ion-selective electrode. APHA 4500-F-C: Online Edition.	0.05 g/m ³
Free Carbon Dioxide	Calculation: from alkalinity and pH, valid where Total Dissolved Solids are not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO ₂ D: Online Edition.	1.0 g/m ³ at 25°C
Hardness	Calculation from Calcium and Magnesium. APHA 2340 B: Online Edition.	1.0 g/m ³ as CaCO ₃
Iron	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B: Online Edition / US EPA 200.8.	0.021 g/m ³
Lead	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B: Online Edition / US EPA 200.8.	0.00011 g/m ³
Magnesium	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B: Online Edition / US EPA 200.8.	0.021 g/m ³
Manganese	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B: Online Edition / US EPA 200.8.	0.00053 g/m ³
Mercury	Bromine oxidation followed by atomic fluorescence. US EPA Method 245.7, Feb 2005.	0.00008 g/m ³

Determinand	Method Used	Detection Limit
Nitrate-N	Filtered sample. Ion chromatography. APHA 4110 B (modified): Online Edition.	0.05 g/m ³
Nitrite-N	Automated Azo dye colorimetry, flow injection analyser. APHA 4500-NO ₃ -I (modified): Online Edition.	0.002 g/m ³
pH	pH meter. APHA 4500-H+ B (modified): Online Edition. Note: It is not possible to achieve the APHA Maximum Storage Recommendation for this test (15 minutes) when samples are analysed upon receipt at the laboratory and not in the field. Samples and Standards are analysed at an equivalent laboratory temperature (typically 18–22°C). Temperature compensation is used.	0.1 pH Units
Potassium	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B: Online Edition / US EPA 200.8.	0.053 g/m ³
Sodium	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B: Online Edition / US EPA 200.8.	0.021 g/m ³
Sulphate	Filtered sample. Ion chromatography. APHA 4110 B (modified): Online Edition.	0.5 g/m ³
Total Dissolved Solids	Calculation: from Electrical Conductivity.	2 g/m ³
Turbidity	Analysis by Turbidity meter. APHA 2130 B (modified): Online Edition.	0.05 NTU
Zinc	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B: Online Edition / US EPA 200.8.	0.0011 g/m ³

APPENDIX 4 DETERMINAND STATISTICS FOR RURAL SCHOOL DRINKING WATER



Determinand	Samples below LOD	Max.	Min.	Median	Mean	Std. Dev.	No. of People Affected	MAV# or AV*
Alkalinity (mg/L as CaCO ₃)	0	280	1.2	47.0	67.1	60.3	0	none
Ammonia (mg/L)	209	1.41	<0.010	<0.010	0.04	0.16	0	1.5*
Antimony (mg/L)	239	0.0087	<0.00021	<0.00021	0.00011	0.00006	0	0.02 [#]
Arsenic (mg/L)	212	0.0179	<0.0011	<0.0011	0.00101	0.00184	301	0.01 [#]
Boron (mg/L)	9	0.58	<0.0053	0.018	0.036	0.062	0	2.4 [#]
Cadmium (mg/L)	234	0.00033	<0.000053	<0.000053	0.000030	0.000024	0	0.004 [#]
Calcium (mg/L)	0	111	0.2	9.7	15.2	17.8	0	None
Chloride (mg/L)	0	167	1.1	11.1	18.6	20.7	0	250*
Chromium (mg/L)	179	0.0081	<0.000053	<0.000053	0.0005	0.0007	0	0.05 [#]
Conductivity (µS/cm)	0	1010	9	173	217.1	164.9	0	None
Copper (mg/L)	15	1.25	<0.00053	0.02	0.07	0.17	0	2.0 [#]
<i>Escherichia coli</i> (counts in 100 mL)	225	435	<1	<1	5.1	34.2	2891	0 [#]
Fluoride (mg/L)	99	1	< 0.05	0.07	0.085	0.088	0	1.5 [#]
Free Carbon Dioxide (mg/L)	15	50	< 1.0	5.0	7.4	7.6	0	None
Hardness (mg/L)	0	340	1	43.0	56.5	58.0	1400	200*
Iron (mg/L)	160	14.6	< 0.021	< 0.021	0.42	1.77	5279	0.3*
Lead (mg/L)	31	0.025	< 0.00011	0.00080	0.0018	0.0032	794	0.01 [#]
Magnesium (mg/L)	3	34.0	< 0.021	3.1	4.5	4.9	0	None
Manganese (mg/L) (MAV)	83	0.5	< 0.00053	0.0012	0.0230	0.0713	138	0.4 ^{**}
Mercury (mg/L)	241	0.0085	< 0.00008	< 0.00008	0.0001	0.0005	133	0.007 [#]
Nitrate-N (mg/L)	30	13.1	< 0.05	0.52	1.60	2.30	35	11.3 [#]
Nitrite-N (mg/L)	205	0.101	< 0.002	< 0.002	0.004	0.012	0	0.91 [#]
pH	79	9.9	5.1	7.3	7.3	0.73		7 to 8.5*
Potassium (mg/L)	0	11.3	0.13	1.51	2.16	1.91	0	none
Sodium (mg/L)	0	151	0.8	12.7	22.9	26.7	0	200*
Sulphate (mg/L)	6	136	<0.5	3.7	7.6	12.6	0	250*
Total Dissolved Solids (mg/L)	0	680	6.0	116	146.1	110.3	0	1000*
Turbidity (NTU)	62	143	< 0.05	0.12	3.1	15.9	4050	5*
Zinc (mg/L)	6	1.91	< 0.0011	0.03	0.01	0.21	554	1.5*

APPENDIX 5 DETERMINAND THRESHOLDS AND EXCEEDANCES

Table A5.1 Determinand thresholds for maximum acceptable value (MAV) and aesthetic value (AV) and the number of exceedances for each determinand based on water type (where B = bore water, S = surface water and T = tap water).


Determinand	Standard	Threshold	Sites ½ MAV to MAV Threshold			Total	Sites > MAV or AV Threshold			Total
			B	S	T		B	S	T	
Alkalinity	None	-	-	-	-	-	-	-	-	-
Ammonia-N*	AV	1.5 mg/L	-	-	-	-	-	-	-	-
Antimony [#]	MAV	0.02 mg/L	-	-	-	-	-	-	-	-
Arsenic [#]	MAV	0.01 mg/L	3	0	3	6	1	1	1	3
Boron [#]	MAV	2.4 mg/L	-	-	-	-	-	-	-	-
Cadmium [#]	MAV	0.004 mg/L	-	-	-	-	-	-	-	-
Calcium	None	-	-	-	-	-	-	-	-	-
Chloride*	AV	250 mg/L	-	-	-	-	-	-	-	-
Chromium [#]	MAV	0.05 mg/L	-	-	-	-	-	-	-	-
Conductivity	None	-	-	-	-	-	-	-	-	-
Copper [#]	MAV	2 mg/L	1	-	2	3	-	-	-	-
<i>Escherichia coli</i> [#]	MAV	0 counts	-	-	-	-	12	5	3	20
Fluoride [#]	MAV	1.5 mg/L	-	-	-	-	-	-	-	-
Free Carbon Dioxide	None	-	-	-	-	-	-	-	-	-
Hardness*	AV	200 mg/L	-	-	-	-	5	1	6	12
Iron*	AV	0.3 mg/L	-	-	-	-	28	-	3	31
Lead [#]	MAV	0.01 mg/L	5	2	7	14	1	-	4	5
Magnesium	None	-	-	-	-	-	-	-	-	-
Manganese [#]	MAV	0.4 mg/L	7	-	1	8	2	-	-	2
Manganese*	AV	0.04 mg/L	-	-	-	-	22	-	6	28
Mercury [#]	MAV	0.007 mg/L	-	-	-	-	1	-	-	1
Nitrate-N [#]	MAV	11.3 mg/L	6	-	14	20	1	-	-	1
Nitrite-N [#]	MAV	0.91 mg/L	-	-	-	-	-	-	-	-
pH*	AV	7.0–8.5	Below pH7			79	Above pH8.5			11
			23	6	50		3	1	7	
Potassium	None	-	-	-	-	-	-	-	-	-
Sodium*	AV	200 mg/L	-	-	-	-	-	-	-	-
Sulphate*	AV	250 mg/L	-	-	-	-	-	-	-	-
Total Dissolved Solids*	AV	1000 mg/L	-	-	-	-	-	-	-	-
Turbidity*	AV	5 NTU	-	-	-	-	20	-	1	21
Zinc*	AV	1.5 mg/L	-	-	-	-	1	-	1	2

APPENDIX 6 EXAMPLE DRINKING-WATER REPORT TO SCHOOLS

<h1>Rural School ID: 1234</h1> <h2>National Rural School Water Quality Results</h2> 					
School Contact: Principal, admin@rural.school.nz, principal@rural.school.nz				Testing Date: 5/03/2024	
Summary of Testing: All parameters are within the expected range.				Water Type: Groundwater sampled from kitchen tap	
Test [Note: mg/L is the same as g/m ³ and ppm]	Primary source and impact	Typical Range	MAV# or AV*	Rural School results Hill Lab ID XXXXXXXX	Green = Acceptable, meets MAV or AV Yellow = Req. monitoring, exceeds ½ MAV or AV, Red = Unacceptable, exceeds MAV or AV
Alkalinity mg/L as CaCO ₃	Important for water quality interpretation and other test parameter estimations.	30 to 400	none	84	●
Ammonia mg/L	Ammonia is a highly soluble gas caused by degradation of organic matter or urea derived from animal waste.	0.01 to 2.0	1.5 *	0.31	●
Antimony mg/L	Derived from metal plumbing and fittings	0.01 to 2.0	0.02 #	< 0.00021	●
Arsenic mg/L	Arsenic can be naturally present at high levels in groundwater and is highly toxic in its inorganic form.	0 to 0.01	0.01 #	< 0.0011	●
Boron mg/L	Boron has been detected in some bores that are linked to geothermal sources and may affect reproductive health development at higher levels .	0.1 to 0.3	2.4 #	0.059	●
Cadmium mg/L	Cadmium is found as an impurity in zinc galvanized pipes. May be higher in waters with lower pH causing plumbing corrosion. Linked to kidney disorders, bronchitis and anemia at higher levels.	0 to 0.004	0.004 #	< 0.000053	●
Calcium mg/L	A major element found in water, and used to calculate hardness. Necessary dietary mineral.	0 to 80	none	17.3	●
Chloride mg/L	A major element found in water and essential for human health. Higher levels indicate salt-water intrusion, and can cause taste and corrosion problems.	0 to 100	250 *	30	●
Chromium mg/L	Derived from natural geological sources and industrial treatments. Higher levels can cause health problems.	0 to 0.05	0.05 #	< 0.00053	●
Conductivity µS/cm	Important as an ion balance check and other testing parameter estimations. Can indicate sea water intrusion. Used to calculate Total Dissolved Solids.	30 to 300	none	260	●
Copper mg/L	Can be leached from copper piping by acidic/corrosive water causing blue/green staining in water. High level may cause gastro-intestinal distress.	0 to 2	2.0 #	< 0.00053	●
E. Coli counts in 100ml	Generally not an issue for groundwater but can be detected in shallow bores. E. coli causes gastro-intestinal distress.	Not usually detected	0 #	< 1	●
Fluoride mg/L	Added to water to prevent tooth decay, but also present naturally in the environment.	0.7 to 1.0	1.5 #	0.1	●
Free Carbon Dioxide mg/L	Higher levels may cause corrosion of copper tubing and other metal plumbing.	0 to 50	none	1.1	●
Hardness mg/L as CaCO ₃	High hardness may cause scale deposition and scum formation. Water with low hardness (<100 mg/L) may be more corrosive. Defined as the sum of calcium and magnesium concentrations. Elevated hardness can affect the efficiency of water treatment processes.	0.1 to 200	200 *	60	●

Maximum Acceptable Value - Water Services (Drinking Water Standards for New Zealand) Regulations 2022. These values are specified for substances which have potential health effects due to prolonged exposure at concentrations above the recommended threshold.

* Aesthetic Value - Aesthetic values for Drinking Water Notice 2022 (Taumata Arowai). Water with values exceeding these guidelines may have undesirable taste or odour issues, or leave residues and staining.

<h1>Rural School ID: 1234</h1> <h2>National Rural School Water Quality Results</h2>					
Test [Note: mg/L is the same as g/m ³ and ppm]	Primary source and impact	Typical Range	MAV# or AV*	Rural School results Hill Lab ID XXXXXXX	Green = Acceptable, meets MAV or AV Yellow = Req. monitoring, exceeds 1/3 MAV or AV, Red = Unacceptable, exceeds MAV or AV
Iron mg/L	High iron is not usually a health issue, but can lead to staining of laundry and sanitary ware.	0.1 to 2	0.3 *	0.028	●
Lead mg/L	Lead is a toxic metal whose widespread historical use (e.g. roof flashing, lead based paint and petrol additive) has caused extensive environmental contamination and health problems.	0 to 0.01	0.01 #	< 0.00011	●
Magnesium mg/L	Major ion, used to calculate water hardness.	0 to 10	none	4.1	●
Manganese mg/L	Staining of laundry. Causes health issues at higher levels.	0 to 0.05	0.04 * 0.4 #	0.025	●
Mercury mg/L	Derived from natural geological sources and industrial processes. Toxic when above maximum acceptable value.	0 to 0.007	0.007 #	< 0.00008	●
Nitrate mg/L as NO ₃ -N	Important plant nutrient, indicative of fertiliser application and other anthropogenic inputs. At higher levels it is a health concern (can cause methaemoglobinaemia in bottle fed infants).	0 to 11.3	11.3 #	0.07	●
Nitrite mg/L as NO ₂ -N	A precursor to nitrates, derived from animal and human wastes, and fertilizers.	0 to 0.91	0.91 #	< 0.002	●
pH	Groundwater that is low in pH can attack metal piping leading to high levels of dissolved metals.	7.0 to 8.5	7.0 to 8.5 *	8.2	●
Potassium mg/L	A major ion that is an essential element for human health.	0 to 8	none	4.3	●
Sodium mg/L	A major ion, indicative of salt water intrusion, can cause taste problems.	5 to 40	200 *	31	●
Sulphate mg/L	A major ion, that can naturally occur in water, or be caused by industrial or domestic wastes. It can cause taste problems.	5 to 50	250 *	1.7	●
Total Dissolved Solids mg/L	Bores close to the ocean can have elevated TDS levels. Water from limestone aquifers can also be high in TDS. May affect water filtration efficiency.	10-500	1000 *	174	●
Turbidity NTU	Elevated turbidity can affect the efficiency of water treatment processes. Odour threshold level is set at <0.3 NTU.	0 to 5	5 *	< 0.05	●
Zinc mg/L	Can be present due to galvanized metal piping. An essential trace element for human health, but can cause health problems at higher levels.	0.02 to 9	1.5 *	0.0013	●

Maximum Acceptable Value - Water Services (Drinking Water Standards for New Zealand) Regulations 2022. These values are specified for substances which have potential health effects due to prolonged exposure at concentrations above the recommended threshold.

* Aesthetic Value - Aesthetic values for Drinking Water Notice 2022 (Taumata Arowai). Water with values exceeding these guidelines may have undesirable taste or odour issues, or leave residues and staining.



Ministry for the
Environment
Mātaua Ake Te Kaitiaki

Contact us:

Schooldrinkingwater@gns.cri.nz

APPENDIX 7 EXAMPLES OF RESULTS EMAILS SENT TO SCHOOLS

A7.1 Green Email (All Determinands below ½ MAV or AV)

National Rural School Water Quality Results

Kia ora [School]

We are writing to provide the analytical report of your recent water testing undertake as part of a Ministry of Education and Ministry for the Environment funded national survey on Rural School drinking water quality.

More than 250 rural schools were invited to take part and your data will form the basis of a report to the Ministry of Education about rural school drinking water quality and whether further support is required to ensure rural school drinking water sources are safe for daily use and in emergency situations.

Your results showed that from a range of 29 different water testing parameters, there were **no concerns raised about the quality of the water** that you submitted for this survey. A full report is attached to this email and provides further information and guidance about the range of expected and acceptable levels for each determinand analysed in this survey.

If you have any further questions about your report, please feel free to contact schooldrinkingwater@gns.cri.nz

Thank you for your participation,

Regards
Dr Karyne Rogers
National Rural School Drinking Water Quality Survey
GNS Science

A7.2 Yellow Email (One or More Determinand Above ½ MAV or AV)

National Rural School Water Quality Results

Kia ora [School]

We are writing to provide the analytical report of your recent water testing undertake as part of a Ministry of Education and Ministry for the Environment funded national survey on Rural School drinking water quality.

More than 250 rural schools were invited to take part and your data will form the basis of a report to the Ministry of Education about rural school drinking water quality and whether further support is required to ensure rural school drinking water sources are safe for daily use and in emergency situations.

Your results showed that from a range of 29 different water testing parameters, there were **[X] exceedances over ½ maximum acceptable value or aesthetic value thresholds** found in the water that you submitted for this survey. A full report is attached to this email and provides further information and guidance about the range of expected and acceptable levels for each determinand analysed in this survey.

While the results indicate that no immediate action is required, the Ministry of Education Water Services Team will be in touch to advise on amending monthly monitoring of your treated water quality to ensure your drinking water remains safe. Any specific issues related to the effectiveness of water treatment are highlighted in the report comments.

If you have any further questions about your report, please feel free to contact schooldrinkingwater@gns.cri.nz

Thank you for your participation,

Regards,
Dr Karyne Rogers
National Rural School Drinking Water Quality survey
GNS Science

A7.3 Red Email (One or More Determinands exceeding MAV or AV)

National Rural School Water Quality Results

Kia ora [School]

We are writing to provide the analytical report of your recent water testing undertaken as part of a Ministry of Education and Ministry for the Environment funded national survey on Rural School drinking water quality.

More than 250 rural schools were invited to take part and your data will form the basis of a report to the Ministry of Education about rural school drinking water quality and whether further support is required to ensure rural school drinking water sources are safe for daily use and in emergency situations.

Your results showed that from a range of 29 different water testing parameters, there were **[X] exceedances over the maximum acceptable value or aesthetic value thresholds and [Y] exceedances of ½ maximum acceptable value or aesthetic value thresholds** found in the water that you submitted for this survey. A full report is attached to this email and provides further information and guidance about the range of expected and acceptable levels for each determinand analysed in this survey.

The results highlight the need for effective treatment of your source water prior to consumption. The Ministry of Education Water Services Team will be in contact to confirm that effective treatment is in place. This will include helping you confirm your water treatment process and recommend any follow-up testing of your treated water. The Ministry will also support any treatment upgrade that might be required and advise on changes to monthly monitoring to ensure water remains safe to drink.

If you have any further questions about your report, please feel free to contact schooldrinkingwater@gns.cri.nz

Thank you for your participation,

Regards
Dr Karyne Rogers
National Rural School Drinking Water Quality Survey
GNS Science