Cadmium in Groundwater: review of regional council data

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by

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SUMMARY

Introduction

Cadmium is a non-essential toxic heavy metal, which may enter the environment through human activities. It is a trace contaminant in superphosphate fertiliser (weighted average cadmium content of superphosphate fertiliser from 2001 to 2005 was 180 mg Cd/kg P). The widespread use of the fertiliser in New Zealand makes this source of cadmium a particular cause of concern.

As a result of the application of superphosphate, cadmium concentrations in the top soil of agricultural areas, although variable, are higher than background levels. The leaching of cadmium from soil by water percolating into the unsaturated zone and eventually into groundwater is a possible mechanism by which groundwater may become contaminated with cadmium. Abstraction of cadmium-contaminated groundwater for water supply purposes may present a risk to public health.

Cadmium from fertiliser application can also be carried into surface waters in runoff. This cadmium is primarily absorbed to particulate matter. The public health risk from cadmium in this form is reduced either through natural sedimentation in the water body or by particulate removal processes during water treatment.

Cadmium can also be dissolved from plumbing materials. This risk is managed through Section 8.2.1.4 of the *Drinking-water Standards for New Zealand*. This section requires water suppliers with plumbosolvent water[1] to advise their consumers to flush their taps briefly before drawing water for use.

The Ministry of Health has funded this study to provide an understanding of whether cadmium in groundwater presents a risk to public health. The study's interest is groundwater cadmium concentrations typically found in a region, not in cadmium concentrations arising from point-source contamination.

Method

Data on which this report is based were obtained from two sources: the *National Groundwater Quality Indicators Update: state and trends 1995–2008* and a direct request to regional councils to obtain data more recent than 2008. All regional councils and unitary authorities (except Nelson City) were asked for data they hold on cadmium concentrations in groundwater in their region. Datasets were received from six councils in time for inclusion in this report.

[1] The term is used in the *Drinking-water Standards for New Zealand 2005 (Revised 2008)* to describe water that causes metals of health concern from fittings or plumbing to appear in consumers' drinking-water.

Key points from the data analysis

1. The majority of median concentrations reported in the national groundwater quality indicators report are below the limit of detection of the test methods used.

2. The cadmium concentration in 87 percent of samples analysed by regional councils is below the limit of detection.

3. Of 1283 results in the combined regional council dataset, only three exceeded 50 percent of cadmium's maximum acceptable value in drinking-water (the maxmimum acceptable value for cadmium is 0.004 mg/L). No cadmium concentrations exceeded the maximum acceptable value itself.

4. Taranaki and the Waikato were the only regions in which data had been collected that allowed testing for trends in the cadmium concentration. No trends were found at the 95 percent confidence level.

5. A qualitative assessment of geographical patterns in cadmium concentrations showed that the median concentrations were the same in all regions and below the limit of detection. The 90th percentile values of groundwater cadmium concentrations in Southland and Canterbury were also below detection, but the 90th percentile concentrations were above the limit of detection in Taranaki, Waikato and the Bay of Plenty – regions where the 90th percentile of soil cadmium concentrations (all land uses) exceeds 1 mg/kg.

Public health implications

The data available to this study show that, generally, groundwaters do not presently contain cadmium concentrations that would constitute a risk to public health if these waters were used for water supply purposes.

This is evident from both the *National Groundwater Quality Indicators Update: state and trends 1995-2008* dataset, and the dataset obtained directly from regional councils. In the latter dataset, no sample contained a cadmium concentration that exceeded 50 percent of the maximum acceptable value. Thirty seven percent of these results showed cadmium concentrations at least a factor of 80 below the maximum acceptable value.

Despite cadmium in groundwater presently not being a public health risk, there are some bores/wells yielding water in which the cadmium concentration is elevated. Water suppliers, when developing a new source, are responsible for undertaking a full investigation of the area to identify possible point sources of cadmium (and other possible contaminants), before development starts.

Management of public health risk associated with cadmium

In general, there is no immediate public health risk arising from cadmium in groundwater. However, water suppliers need to be aware of the possibility of cadmium eventually being leached from soil into groundwater in areas with intensive agriculture. To manage this public health risk cadmium should be included in monitoring undertaken for identifying chemical hazards as part of the periodic review of water safety plans. Where possible, the water supplier should also review monitoring data obtained by regional councils through their monitoring programmes.

Where the cadmium concentration already exceeds the maximum acceptable value in a groundwater used for drinking purposes, a new source should be sought for drinking and cooking purposes.

Assessment of the project methodology

With reference to future studies to update understanding of potential risk to public health from water supply sources, there are advantages to obtaining data from regional councils.

a. Datasets can provide good geographical coverage.

b. Time series are sometime available, which allows limited investigation of trends.

c. Sampling and analysis costs are avoided.

However, there are also difficulties associated with obtaining data from regional councils or with the data itself.

a. Unresponsiveness, or slow responses, from councils can be experienced.

b. Some regional council data are derived from investigations that target high cadmium concentrations, which can provide misleading indications of the typical levels of a determinand throughout a region.

c. Data for determinands of health importance are often limited.

d. There is not necessarily any consistency in the analytical methods used by different councils, which can lead to mixed limits of detection and different forms of the determinand being reported.

Some of these difficulties should not be a surprise because the use of the data for public health purposes is different from that for which the regional councils originally collected the data.

Although there are drawbacks in making use of regional council data, asking the councils for data still appears preferable to approaching water suppliers for source water data they may have, or establishing a national monitoring programme specifically for the project.

An important first step in possible future studies is to get an improved understanding of the extent and limitations of the datasets regional councils hold. Visits to regional councils may be a better way of achieving this than requests for information by email.

Conclusion

At present, there is no evidence of a widespread problem of cadmium groundwater concentrations exceeding the metal's maximum acceptable value. There may be some sites where localised cadmium concentrations exceed the maximum acceptable value. Hazard identification undertaken during the development and implementation of water safety plans should identify such sites and the measures necessary for minimising the public health risk.

The approach to this type of investigation of asking regional councils for datasets does have its difficulties, but appears preferable to the alternatives. The success of using this source of data may lie in a scoping step in the project. This would aim to establish a relationship with appropriate council and determine what data the council holds and its possible limitations with respect to the Ministry's needs.

1 INTRODUCTION

1.1 Background

The *Drinking-water Standards for New Zealand 2005* (revised 2008) (the Standards) lists 115 chemical determinands for which maximum acceptable values are specified. Monitoring for all of these determinands would be time-consuming, expensive and unnecessary. To make more effective use of available resources, the Standards use a priority system for determining which determinands a water supplier has to monitor. This system requires all water suppliers to monitor Priority 1 determinands to show that the water is safe from microbiological contaminants. The monitoring of Priority 2 determinands is supply-specific. Chemical determinands are classified as Priority 2 determinands if they are present at concentrations in excess of 50 percent of their maximum acceptable value. Not all chemicals listed in the Standards will exceed 50 percent of their maximum acceptable value in a water supply. Consequently, the determinands that each water supplier has to monitor have to be identified. Identifying chemical hazards that may threaten the quality of a water supply is the water supplier's responsibility. This is one of the functions of the supply's water safety plan.

Once a Priority 2 determinand is assigned to a treatment plant or supply zone, to comply with the Standards the water supplier must monitor the determinand's concentration. Monitoring continues until the water supplier can show that measures taken have reduced the determinand's concentration to less than 50 percent of its maximum acceptable value. Chemical determinands that are not classified as Priority 2, are Priority 3 (or possibly Priority 4), by default. The monitoring of Priority 3 and 4 determinands is at the discretion of the water supplier.

Water suppliers have responsibility for periodically checking that Priority 3 determinands do not change in concentration and consequently require reclassification as Priority 2 determinands. Awareness of risk factors specific to their supply that may affect the concentrations of chemical determinands in the water helps the water supplier in this task.

When risk factors could be important nationally, the Ministry of Health (the Ministry) may undertake investigations to understand better these factors and their possible effect on public health. Information gathered from these investigations will be used to decide what actions, if any, are necessary to help water suppliers manage the public health risk these factors present.

The study reported here is the first such investigation for the Ministry. Its purpose is to review data available from regional councils to assess the possibility of cadmium causing a risk to public health in supplies sourced from groundwater. The study's interest is in the groundwater cadmium concentrations typically found in a region, not in cadmium concentrations arising from point-source contamination.

1.2 Why might cadmium be a concern?

Superphosphate is an extensively used fertiliser in New Zealand (MAF 2008). A naturally-occurring contaminant within the phosphate rock from which the superphosphate is produced is cadmium. Superphosphate manufacturers in New Zealand have voluntarily imposed a limit of 280 mg Cd/kg P to help reduce the amount of cadmium being applied to land. From 2001-2005 the weighted average content of the fertiliser was 180 mg Cd/kg P.

As a result of its presence in superphosphate, cadmium, which is a non-essential toxic heavy metal, is applied to agricultural, horticultural and forestry land with fertiliser. While not the only potential source of cadmium in the New Zealand environment, superphosphate is the source of greatest concern.

In 2005 a report was prepared for the Waikato Regional Council on cadmium in agricultural soil in the region, because of the amounts of superphosphate applied in the Waikato (Kim 2005). The report estimated 8.3 tonnes of cadmium were being applied annually to soils in the region primarily through the use of superphosphate.

The Waikato report was a contributing factor for the decision by central government and regional councils to form a Cadmium Working Group. In 2008, the working group prepared a report for the Ministry of Agriculture and Forestry "…to investigate and assess the potential risks surrounding cadmium in New Zealand's agriculture and food systems, and to develop responses as required" (MAF 2008).

Figure 3.3 of the working group's report shows levels of cadmium in top soil throughout the country. While data were scarce in some regions, it is clear from the figure that the Bay of Plenty, Waikato and Taranaki regions are those with the highest topsoil concentrations of cadmium. All had recorded soil cadmium concentrations in excess of 1 mg/kg of soil. To put this in context, the Ministry for the Environment's soil contaminant standard for cadmium is 0.3 mg/kg of soil for a rural or lifestyle block where 25 percent of the food the residents consume is home-grown (MfE 2012). The acceptable level of cadmium in soil extends to 1300 mg/kg where the land is used for industrial or commercial purposes.

The presence of cadmium in top soil raises the concern that leaching of cadmium from the soil may result in its eventual appearance in groundwater. Kim (2005) states that 5 to15 percent of cadmium applied to the soil is lost through leaching. The rate of leaching increases with decreasing groundwater pH because increased acidity retards adsorption of the cadmium and enhances its desorption. Increasing total groundwater drainage also increases leaching.

Kim noted that despite the possibility of cadmium leaching to groundwater, the data collected to that time showed only low concentrations in groundwater. He expected that progressive re-adsorption down the soil profile will, with time, lead to a plume of cadmium enrichment in the subsoil.

For some soils, re-adsorption of cadmium as it leaches from the topsoil may provide protection for groundwater for the foreseeable future. However, the character of the soil determines its capacity to adsorb cadmium. Sandy and stony soils, and those with low levels of organic matter adsorb cadmium poorly, and therefore provide a poorer barrier to cadmium reaching the groundwater.

Cadmium from fertiliser application can also be carried into surface waters in runoff. However, this cadmium is primarily absorbed to particulate matter (Kim 2005). The public health risk from cadmium in this form is reduced either through natural sedimentation in the water body or by particulate removal processes during water treatment.

Cadmium can also be dissolved from plumbing materials. This risk is managed through Section 8.2.1.4 of the *Drinking-water Standards for New Zealand*. This section requires water suppliers with plumbosolvent water[2] to advise their consumers to flush their taps briefly before drawing water for use.

In summary, soil, to a greater or lesser extent, provides a cadmium reservoir, which is continually replenished where fertiliser is applied to the land. Cadmium also leaches from this reservoir. While re-adsorption can limit the amounts of cadmium reaching groundwater, changes in subsurface conditions, and the continual leaching of cadmium by water percolating from the surface, may eventually lead to cadmium reaching the groundwater. As the time scale on which any breakthrough may occur is unknown, the absence of cadmium at concerning levels in groundwater in the past or present does not guarantee that the metal will remain at safe levels in groundwater-sourced supplies in the future.

1.3 Report structure

Section 1	Introduction to the study including an outline of the priority system contained in the Standards, and the reason for cadmium being the focus of this study
Section 2	Description of the method used to undertake the study
Section 3	Summary and analysis of the data collected including discussion of the characteristics of the data by region, and assessments of temporal trends and geographic patterns
Section 4	Assessment of the public health risk associated with cadmium in groundwater and suggested measures for managing this risk
Section 5	Review of the methodology used in the study, which identifies the pros and cons of requesting data from regional councils and suggests steps that might be taken in future to minimise the problems experienced in this work.
Section 6	Conclusion

[2] The term is used in the *Drinking-water Standards for New Zealand 2005 (Revised 2008)* to describe water that causes metals of health concern from fittings or plumbing to appear in consumers' drinking-water.

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2 METHOD

2.1 Data used in the study

Cadmium concentration data in groundwaters were obtained from two sources for the compilation of this report.

a. Ministry for the Environment's *National Groundwater Quality Indicators Update: state and trends 1995–2008* (Daughney and Randall 2009).

   This report was prepared for the Ministry for the Environment by the Institute of Geological and Nuclear Sciences. It is a compilation of data obtained from sites used for State of the Environment monitoring programmes run by regional councils and data from the Institute's National Groundwater Monitoring Programme. As the title of the report states, the focus is on indicators. As a consequence, the programme's suite of determinands is not comprehensive. Data for several health-significant determinands are absent.

   The results in the Daughney and Randall report are provided as median values. Consequently, the extent to which individual concentrations may extend beyond the median is unknown.

b. Data requested directly from regional councils specifically for this report

   All regional councils were asked for groundwater data they hold on cadmium in groundwater (except Nelson City Council). At the time of preparing this report, data had been received from six regional councils. The limited response may show that few councils have cadmium groundwater data to provide, although only three councils replied saying they had no data available. This was certainly true in 2008 when Daughney and Randall prepared their report. The departure from the council of the staff who took samples and who knew the reasons for their collection may also have contributed to delays in responses to queries about the data.

   Some of the data provided were from investigatory monitoring of sites where elevated cadmium concentrations were expected. These data are not indicative of the groundwater quality in the region as a whole, and are of little value to this work. They are discussed later in the report.

The data from the two sources (a and b above) are analysed separately because one source (a) reports data medians and the other individual sample results. Regional datasets are also examined separately.

2.2 Statistical analysis

Analysis of time series for trends was carried out using the Mann-Kendall test. The Mann-Kendall S statistic was calculated using an Excel® spreadsheet obtained from the Internet Based Information System for Public Health website (http://www.ibisph.org/trac). The S statistic was compared with the critical value, which was determined by the number of data points in the time series and the required alpha value (0.05, 95% confidence for this study). All time series tested contain fewer than 10 data points. A minimum of five data points is required to be able to provide a test result with a 95 percent level of confidence.

3 DATA ANALYSIS

3.1 Introduction

This section presents, analyses and discusses the data collected by the study. It provides the basis for assessing the public health implications of the data which are discussed in Section 4.

3.2 Data from the National Groundwater Quality Indicators report

The dataset collated for the National Groundwater Quality Indicators report shows that, over the period from 1995 to 2008, data for cadmium concentrations in groundwater were collected in only three regions: Waikato, Bay of Plenty and Marlborough. A summary of the cadmium data contained in this collation is presented in Table 1.

Table 1 Summary of data relevant to cadmium from the *National groundwater quality indicators update: state and trends (1995–2008)*

Number of data points	**Range of bore depths (m)**	**Highest median concentration (mg/L)**	**Summary of reported cadmium median concentrations (mg/L) (Result : number of data points)**
Maximum acceptable value for cadmium = 0.004 mg/L			
Environment Bay of Plenty			
47	5.2–375	0.0002	<0.00004 : 5 <0.00005 : 26 0.00005 : 4 0.0001 : 10 0.0002 : 2
Environment Waikato			
88	2.75–127	0.0003	<0.00005 : 31 <0.000053 : 45 0.0001 : 9 0.0002 : 2 0.0003 : 1
Marlborough District Council			
10	5.8–189	0.0004	<0.0005 : 7 0.0005 : 1 0.0003 : 1 0.0004 : 1

The data presented in Table 1 show that in all three regions a substantial majority of median cadmium concentrations were undetectable and that the reported limit of detection was well below the current maximum acceptable value for cadmium of 0.004 mg/L. Furthermore, the maximum reported median concentration in each region was at least an order of magnitude less than the maximum acceptable value.

Maximum cadmium concentrations measured in individual samples are unavailable for this dataset.

3.3 Up-date data obtained directly from regional councils for this study

3.3.1 Introduction

A summary of the up-date data obtained from five regional councils specifically for this study is presented in Table 2. Data from the Horizons Regional Council and some from the Taranaki Regional Council are not relevant to this study and are omitted from Table 2. The reason for this is explained later in this section.

Table 2 shows that four different forms of cadmium are reported in the five regional datasets. The Standards do not explicitly state the form of cadmium to which the maximum acceptable value relates. However, the referee method measures the total metal concentration, inferring that this is the form of cadmium relevant to the maximum acceptable value. For this reason, total cadmium results, in preference to other reported forms of cadmium, are used in assessment of the data, wherever total concentrations are available.

The samples in which acid-soluble cadmium has been determined are primarily those from investigatory studies, in which high cadmium levels are likely. The least sensitive limit of detection reported for this method (there are several) is 0.005 mg/L. This limit is greater than the maximum acceptable value, consequently, where a concentration is reported as “<0.005 mg/L”, the health significance of the cadmium in the sample cannot be determined.

Each regional data set is considered separately in the subsections that follow Table 2.

Table 2 Summary of cadmium data received directly from regional councils that are relevant to understanding cadmium concentrations in groundwater that may be used for drinking-water

Number of data points	Range of concentrations (mg/L)	Form of cadmium reported	Median[1] (mg/L)	90th Percentile (mg/L)	Comments
Maximum acceptable value for cadmium = 0.004 mg/L					
Bay of Plenty Regional Council					
90	<0.00005–0.002	Dissolved	0.000025	0.00022	Non-detects reported in 67 samples
Environment Canterbury					
305	<0.00005–0.00178	Total	0.000025	0.000025	Non-detects reported in 298 samples
Environment Southland					
64	<0.00005–<0.0003	Dissolved	0.000025	0.000025	Non-detects reported in 64 samples
Waikato Regional Council					
762	<0.00005–0.0021	Total (755) Dissolved (7)	0.000027	0.000089	Non-detects reported in 634 samples
Taranaki Regional Council					
62	<0.00005–0.001	Total (5) Dissolved (44) Dissolved (by AAS) (5) Acid soluble (8)	0.000025	0.0025	Non-detects reported in 52[2]

[1] To calculate the median "less than" values were recorded as 50 percent of the limit of detection.

[2] The detection limit in 13 of these samples was too high to allow an assessment to be made of whether the concentration exceeded the maximum acceptable value. These samples were not included in the concentration range (2nd column from the left).

3.3.2 Bay of Plenty Regional Council data

The results obtained from the Bay of Plenty Regional Council relate to samples taken over the period from 2008 to 2013. The dataset contains no cadmium concentrations reported as undetectable.

Sixty seven of the 90 samples contained concentrations less than the detection limit of 0.0005 mg/L. Only one sample is reported to have contained a cadmium concentration of slightly more than 50 percent of the maximum acceptable value, and no samples exceeded the maximum acceptable value.

The only form of cadmium reported in the Bay of Plenty dataset is dissolved cadmium. This prevents comparison of dissolved and total concentrations to gain an understanding of how the two fractions relate to each other. Many samples from Waikato Regional Council have results for both total and dissolved cadmium. These show that the difference between the two fractions in that region is quite variable with the dissolved fraction sometimes reported as being larger than the total concentration. This is indicative of a large percentage uncertainty in the measurements at low concentrations. It shows that within the measurement uncertainties differences between the two fractions at low concentrations cannot be reliably identified.

3.3.3 Environment Canterbury data

Total cadmium concentrations are available for all samples obtained from Environment Canterbury. A high percentage of the samples (298 of 305) contained undetectable concentrations of cadmium. The highest concentration of cadmium reported was less than 50 percent of the maximum acceptable value (0.00178 mg/L) and all other detectable concentrations (6 samples) were less than 3 percent of the maximum acceptable value.

The Canterbury data were all collected in 2012.

3.3.4 Environment Southland data

All data from Environment Southland are dissolved cadmium concentrations. The cadmium concentrations in all 64 samples were reported to be undetectable (<0.00005 mg/L) except in one sample in which the concentration was less than one tenth of the maximum acceptable value (0.0003 mg/L).

The Southland data were all collected in 2012.

3.3.5 Waikato Regional Council data

The Waikato Regional Council is aware of the potential problem of cadmium associated with the use of superphosphate in the regional environment because of the high rates of use of the fertiliser by the dairy industry (Kim, 2005). This is reflected in the high number of samples (762) taken in the region and the fact that the results were collected over an extended period (2008 to 2012). Total cadmium concentrations were measured in all except seven of the samples.

Sample descriptions did not accompany all samples. Where descriptions are present they record a street or road address. There is no indication that samples were taken in association with contaminated sites.

In 634 of the 762 samples the cadmium concentration was below the limit of detection. The maximum concentration reported was 0.0021 mg/L, slightly greater than 50 percent of the maximum acceptable value.

3.3.6 Horizons Regional Council data

The Horizons Regional Council is not routinely taking samples for cadmium analysis to assess concentrations in general environmental samples. Seven results were received from the council, all taken in April 2008 from bores sunk for leachate monitoring at a landfill. All results were reported as less than 0.001 mg/L. These data are not included in the data assessment because the sampling locations were not representative of groundwater throughout the region.

3.3.7 Taranaki Regional Council data

The Taranaki District Council's data spans the period from 2000 to 2013. Four different forms of cadmium are reported (see Table 2). The limit of detection reported in the measurements is 0.00005 mg/L, except for the 13 samples reported as "Dissolved (AAS)" and "Acid soluble" for which the limits of detection are 0.005 mg/L. Overall, the cadmium concentration is reported to be below the detection limit of the method of analysis used in 52 of 62 samples. However, where the limit of detection is 0.005 mg/L, exceedence of cadmium's maximum acceptable value cannot be determined.

Included in the data received from the Taranaki Regional Council were cadmium concentrations in samples taken from landfill monitoring bores, the Ravensdown site in New Plymouth, and a site where fertiliser has been stored in the past. These have not been included in the data in Table 2 because the locations are essentially contaminated sites, where high cadmium concentrations would be expected. They are not representative of groundwater concentrations throughout the region.

The Ravensdown data are unhelpful for informing an assessment of cadmium in waters that might be used as water supply sources. However, they are a reminder that there can be high localised concentrations of cadmium in groundwaters. Such sites need to be identified and their potential influence on a new drinking-water source in the area understood before the source is developed for use.

Cadmium was not found to exceed the maximum acceptable value in any sample which was both included in Table 2 and analysed using a method with a limit of detection below the maximum acceptable value.

3.3.8 Summary of the datasets as a whole

As discussed in Section 3.3.6 and Section 3.3.7, the data from Horizons Regional Council and some of the data from the Taranaki Regional Council are irrelevant to the purpose of this report. They are not considered in the assessment of the health risk associated with cadmium in groundwater in Section 4.2.

Of the 145 median results reported in Table 1, 114 are undetected and no median is greater than 10 percent of the maximum acceptable value.

Table 2 contains 1283 results. Of these, 1115 (87%) are reported as having an undetectable cadmium concentration. Only three samples contained cadmium concentrations exceeding 50 percent of the maximum acceptable value. Thirty seven percent of the 1283 results showed cadmium concentrations at least a factor of 80 below the maximum acceptable value.

Viewed as a whole, the results show that the cadmium concentrations found in groundwaters that might be considered for drinking-water abstraction purposes are low. Insufficient information was received from the regional councils to understand the possible reasons why the cadmium concentrations in some waters exceeded 50 percent of the maximum acceptable value. This concentration is of interest because it is the demarcation point for assigning cadmium as a Priority 2 determinand for the purposes of the Standards.

3.4 Temporal trends

Although cadmium concentrations in groundwater are generally low at present, Section 1.2 identifies factors that could lead to an increase in groundwater concentrations in future. This section examines the datasets for evidence of cadmium concentrations changing with time.

3.4.1 National Groundwater Quality Indicators dataset

Trends were assessed as part of the data analysis undertaken for the *National groundwater quality indicators update: state and trends (1995–2008)* report. No trends in the cadmium data were reported.

3.4.2 Update dataset from regional councils

Data collected over time for specific sites are only found in the datasets from Waikato and Taranaki.

a. Waikato

The Waikato Regional Council’s dataset contains samples from 42 locations from which five or more samples have been taken. However, of these 42 time series only 12 contain one or more samples in which the cadmium concentration was detectable. Testing for a trend using the Mann-Kendall test showed no trend in the cadmium concentration at the 95 percent confidence level in any dataset.

b. Taranaki

Apart from samples obtained from the Ravensdown and landfill sites, 12 sites in Taranaki provide time series with five or more samples. None of these series shows a trend using the Mann-Kendall test at the 95 percent confidence level.

3.5 Geographical patterns

The regional data for cadmium in soils contained in the Cadmium Working Group report (MAF 2008) show that there is variation between regions. Factors such as rates of fertiliser application and soil type contribute to these differences. The volcanic origins of much of the soil in the Waikato, Bay of Plenty and Taranaki may contribute to the levels of cadmium they contain. Conversely, the low soil concentrations in Canterbury and Hawke's Bay regions reflect the fact that these are derived from alluvial gravels. As there are regional differences in soil concentrations, if there is sufficient leaching from the soil for cadmium to reach the groundwater, regional differences in groundwater cadmium concentration might also be expected.

The median values and 90th percentiles in Table 2 give an idea of the distribution of cadmium concentrations in each region. The median values are essentially the same in all datasets, indicating that, in all five regions, at least half the samples contain low cadmium concentrations. It is the upper end of each distribution (90th percentile) where possible differences between the datasets become evident. The 90th percentiles in Southland and Canterbury, where soil cadmium concentrations are lower, are the same as the median, while in the other three regions where soil levels are higher the 90th percentiles are in the detectable range.

While elevated groundwater concentrations may seem to be associated with elevated soil concentrations, the 90th percentile of the data from Waikato, is probably indistinguishable from its median, given the uncertainty in the low concentration range noted in Section 3.3.2.

In summary, although the majority of groundwater samples in all five regions contained very low cadmium concentrations, there are differences between regions in the cadmium concentrations in the relatively few samples in which the metal was detected. This difference is more evident in some regions with high soil concentrations than others.

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4 DISCUSSION

4.1 National coverage and associated limitations

Data were received from only six regional councils which raises the concern of whether the data available are representative of the rest of the country and will public health conclusions based on the limited dataset be valid.

Cadmium may arise in groundwater from natural and anthropogenic sources. Provided neither of these sources of cadmium is high in the regions for which data were not received, the public health risk from cadmium in groundwater in these regions should be no greater than the risk in the regions included in this review.

The Cadmium Working Group report (MAF 2008) states that soil samples from New Zealand's conservation estate and non-agricultural areas show that the national average baseline (background) soil concentration is approximately 0.16 mg/kg. This level is consistent across all regions and soil types. The observation implies that there are no **naturally-occurring** "hotspots" of cadmium in the country, which might affect groundwater quality. Consequently, the omission of data from some regions is unlikely to have resulted in high concentrations of cadmium in groundwater from **natural** sources being overlooked.

Anthropogenic sources of cadmium are those most likely to have an impact on public health through drinking water. Of these, the most widespread is cadmium derived from superphosphate fertiliser. This report contains data from the regions in which the likelihood of elevated cadmium concentrations in groundwater is highest on the basis of the cadmium concentrations determined in their soils. Provided there is no evidence of cadmium in groundwater being a concern in these regions, it is unlikely that cadmium will be a concern in the regions from which data were not obtained.

4.2 Assessment of the public health risk associated with cadmium in groundwaters

The results presented in Section 3 show that reported cadmium concentrations are generally very low, and that they rarely (three in 1283 samples (0.2%)) exceed 50 percent of the maximum acceptable value. The maximum acceptable value is not exceeded in any samples.

Given these statistics, the argument presented in Section 4.1, and the maximum acceptable value being set at a concentration considered unlikely to be a risk to health over a lifetime of consumption, we conclude that, in general, cadmium concentrations in groundwater are **presently** too low to create a hazard to drinking-water supplies sourced from groundwater.

The caveat to this conclusion is that there may be "hotspots" where cadmium concentrations are high. It is the responsibility of the water supplier, when developing a new source, to undertake a full investigation of the area to identify the presence of hotspots, determine the cadmium concentrations in the groundwater associated with the cadmium source, assess the risk to the health of their customers, and if necessary determine how the risk can be mitigated.

4.3 Next steps for managing the health risk associated with cadmium in groundwater

The data available for this study show that cadmium in groundwater is not presently a public health risk. They also provide no evidence of the cadmium concentrations increasing with time (Section 3.4.2). However, as discussed in Section 1.2, the continued application of fertiliser and leaching of cadmium from the soil, could eventually lead to increasing concentrations in groundwater under some circumstances. The rate at which this might happen is unknown, but it can be expected to be more rapid in soil types with a diminished capacity to adsorb cadmium.

Because of this possibility water suppliers using groundwater sources in agricultural areas where superphosphate is used should maintain a watch on cadmium levels in their source water. This is most important in regions where fertiliser application is heaviest.

Water suppliers could approach this in two ways.

a. Implementing their own sentinel monitoring programme

   A sentinel monitoring programme would require periodic sampling of the supply's water. Sampling does not need to be very frequent because any increase in the groundwater cadmium concentration is likely to be slow. Cadmium could be added to the list of determinands the water supplier includes in their monitoring programme for chemical hazard identification undertaken at least once every five years as part of the water safety plan review cycle.

b. Reviewing regional council water quality data or summary reports

   This measure is to help the water supplier develop an understanding of how groundwater cadmium levels in the overall region are changing. It should provide forewarning of the need to increase the frequency of the water supplier's own sampling. The ability to take this step depends on the regional council including cadmium in its monitoring suite.

Water suppliers need to be most vigilant in circumstances in which risk factors for cadmium reaching groundwaters are greatest. These include regions with high rates of superphosphate application and areas where soils have poor cadmium adsorption capacity. Shallow bores are expected to be more vulnerable to cadmium leaching. Based on the assumption that the application rate of superphosphate contributes to the high soil cadmium concentrations in Taranaki, Waikato and Bay of Plenty, water suppliers drawing groundwater in these areas, in particular, need to be aware of the possibility of cadmium leaching into groundwater.

As the Ministry for the Environment identifies cadmium as a priority contaminant (MfE, 2012) regional councils may increase their monitoring of groundwater cadmium concentrations. The adoption of consistent sampling and analytical procedures by regional councils will allow comparison of results nationally and over extended periods of time.

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5 METHODOLOGY REVIEW

5.1 Introduction

This study is intended as the first in a series to update our understanding of the potential risk to public health that chemical determinands in water supply source waters pose. It has relied on the collection of data from external organisations (regional councils). Through preparing the report, it has been possible to assess the success, or otherwise, of using this approach as the basis for the study.

This section discusses the pros and cons of this approach to data collection and what modifications should be considered to address the approach's short-comings if it is to be used again in the proposed series of studies.

5.2 Advantages of the approach used for this study

From the Ministry of Health's viewpoint, basing studies on data obtained from regional councils has several advantages.

a. Datasets from councils provide information from a much greater number of locations than can data collected by water suppliers from their own sources, thereby giving a more representative indication of regional groundwater quality.

b. Time series data are available from some sampling locations. This is potentially helpful in identifying trends that provide warning of a determinand reaching concentrations of health concern in the future.

c. The expense of establishing a monitoring programme and the analytical costs associated with it are avoided.

5.3 Difficulties associated with the study's methodology

Several difficulties were encountered with using regional council data for the study. Some of these arise from using the data for a purpose different from that for which the data were originally collected.

a. While datasets were obtained from six regional councils, no response was received from others. Some councils responded rapidly to requests for background information about sampling locations, but not all. Whether this difficulty arises because of a reluctance to assist other agencies, or because council staff are busy and the requests were not considered to be of high enough priority, is unknown. The timeliness of response may depend on which staff member receives the request.

b. Some regional council data were collected as part of an investigation, rather than a surveillance activity. This may result in data that give a misleading indication of water quality in the region for surveillance purposes unless background information supplied with the water quality data make this clear.

c. The range of determinands included in regional council monitoring programmes may not include determinands of public health interest. The national groundwater quality indicators dataset shows this.

d. Drawing data together from several councils may mean having data obtained using a mix of analytical methods so that different forms of the determinand and different limits of detection may be reported. This complicates data interpretation.

5.4 Possible methodological modifications for future studies

The use of regional council datasets certainly presents difficulties, but the difficulties associated with data collection by other approaches may be greater. Section 5.3 identifies what should be addressed if regional council data are to be used in future studies. This section considers what other data sources might be used, and how the problems with the use of regional council data might be mitigated.

5.4.1 Other water quality data sources

Apart from accessing regional council data, there are two other possible sources of water quality data.

a. Water suppliers

   Some water suppliers collect chemical water quality data. Ideally, all water suppliers should do this in order to understand the character of the water they treat. In reality, the extent to which this is done is influenced by how well resourced the water supplier is, what they believe they already know about health significant determinands in their water, and the level of the community's interest in any well-publicised contaminants.

   A large percentage of suppliers provide water to small communities. These suppliers will usually not have the resources, need or interest in continued sampling of their source water for a comprehensive suite of determinands. This will limit the range of determinands for which data may be available, and, because of the relatively small number of suppliers collecting data about their source water, geographical coverage will also be limited.

   Collection of data from each site requires interaction with a separate water supplier (as opposed to one contact for a region when working with regional councils). This would increase interaction overheads should use of this source of information be considered.

b. Monitoring undertaken specifically for the study

This approach would be time-consuming (coordination of sampling teams) and expensive (labour analytical costs). Unless a longitudinal monitoring programme was used to provide data over a period of time, the derived dataset would provide no information about trends.

5.4.2 Working with regional councils and unitary authorities

An important feature of future studies, to optimise their value, is to assign a first step in the project to understand what data are available and how they can best be obtained.

A scoping step (even as a standalone project) could survey regional councils to identify the determinands for which they hold data and how extensive their dataset is. This information will help in deciding which determinands can be the focus of studies in the proposed series. Council reactions to being paid for their time in providing the datasets could also be canvased. A financial arrangement may improve the timeliness of responses.

The survey could be undertaken by email, but that approach also risks a poor response.

A further step to improving council responsiveness is the development of a relationship with appropriate council staff through visits to the council. The effort required in doing this may be rewarded by improved data availability. It is an important consideration if a series of studies is intended.

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6 CONCLUSION

The use of superphosphate fertiliser, which contains cadmium as a trace contaminant, has led to the accumulation of cadmium in soils in parts of New Zealand where the fertiliser is applied. In these areas, soil cadmium concentrations exceed background levels. The possibility of cadmium leaching from the soil into groundwater cannot be ruled out, and consequently there is the risk of cadmium contamination of ground water sources used for water supply.

This study has aimed to assess the level of public health risk arising from cadmium in groundwater sources, based on data received from regional councils. The study's interest has been in the groundwater cadmium concentrations typically present in a region, not in cadmium concentrations arising from point-source contamination.

At present, there is no evidence of a **widespread** problem of cadmium groundwater concentrations exceeding the metal's maximum acceptable value, or even 50 percent of this value. From this it is concluded that generally cadmium concentrations in groundwater are **presently** too low to create a hazard to drinking-water supplies sourced from groundwater.

However, there may be some sites were **localised** cadmium concentrations exceed the maximum acceptable value. Hazard identification undertaken during the development and implementation of water safety plans should identify such sites and the measures necessary for minimising the public health risk.

Time-series data were available from a limited number of sites. No evidence was found of a trend in the cadmium concentrations at these sites. Although there is presently no sign of an upward trend in cadmium groundwater concentrations, the possibility of cadmium leaching from soils into groundwaters exists. This is more likely to occur in soils with a poor capacity to adsorb cadmium. The present understanding of the migration of cadmium within the subsurface is insufficient to allow guidance on the likelihood of cadmium becoming a public health concern or the timeframe over which this may happen.

The approach to this type of investigation of asking regional councils for datasets does have its difficulties, but appears preferable to the alternatives. The success of using this source of data may lie in a scoping step in the project. This would aim to establish a relationship with appropriate council staff, determine what data the council holds and identify its possible limitations with respect to the Ministry's needs.

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REFERENCES

Daughney C, Randall M. 2009. *National Groundwater Quality Indicators Update: State and Trends 1995–2008*. GNS Science Consultancy Report 2009/145. Wellington: Ministry for the Environment. URL: http://www.mfe.govt.nz/publications/ser/groundwater-quality-trends-2008/ (accessed 4 April 2014).

Kim N. 2005. *Cadmium Accumulation in Waikato Soils*. Technical Report 2005/51. Enviornment Waikato. URL: www.waikatoregion.govt.nz/PageFiles/11184/TR2005-51.pdf. (accessed 8 April 2014).

MAF. 2008. *Report One: Cadmium in New Zealand Agriculture* – report of the Cadmium Working Group. Wellington: Ministry of Agriculture and Forestry. URL: http://maxa.maf.govt.nz/mafnet/rural-nz/sustainable-resource-use/land-management/cadmium-in-nz/report-one/. (accessed 8 April 2014).

MfE. 2012. Users' Guide: National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health. Wellington: Ministry for the Environment. 100 pp. URL: http://www.mfe.govt.nz/publications/rma/users-guide-nes-for-assessing-managing-contaminants-in-soil/guide-nes-for-assessing-managing-contaminants-in-soil.pdf (accessed 15 May 2014).

MoH. 2008. *Drinking-water Standards for New Zealand 2005 (Revised 2008*). Wellington: Ministry of Health. URL: https://www.health.govt.nz/publication/drinking-water-standards-new-zealand-2005-revised-2008 (accessed 8 April 2014).

APPENDIX – REPORT DISTRIBUTION

Copies have been made and distributed to:

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