Report One:
Cadmium in New Zealand Agriculture

Report of the Cadmium Working Group
August 2008

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Executive Summary Report of the Cadmium Working Group

Summary of risks from cadmium in agricultural soils

Chapter 1: Setting the context - an introduction to the cadmium issue

Overview

Cadmium naturally occurs in phosphate rock, from which phosphate fertiliser is made. Phosphate fertiliser use underpins agricultural production and therefore contributes significantly to New Zealand's economy. Cadmium tends to accumulate in soils with ongoing application of phosphate fertilisers, and there is evidence that cadmium levels in New Zealand's soils are increasing. This raises the potential for higher cadmium concentrations in some food products grown on soils with elevated cadmium levels. Excessive levels of cadmium in food can have implications for human health, market access and trade, and the ability to change from one land use to another.

Background

Cadmium is a naturally-occurring, non-essential heavy metal which is present at low concentrations in air, water and soils. Both acute and chronic cadmium exposure can have adverse health effects on people.

In New Zealand, industrial exposure to cadmium is rare, and the main source of cadmium for New Zealanders is in tobacco products and food. Low levels of cadmium in the diet can accumulate within certain body organs over a person's lifetime. The New Zealand Food Safety Authority has estimated the amount of cadmium in the diet of the average New Zealander is at a level far below that which would cause adverse health effects.

Phosphate fertilisers contain cadmium as a trace impurity, and cadmium tends to accumulate in soil with repeated application of phosphate fertiliser. Accumulation rates in soils vary between regions of New Zealand due to differences in land use history, phosphate fertiliser cadmium content, total fertiliser use, soil types, climate, and a number of other variables.

There are three key threads to the New Zealand context relating to cadmium in soils, which influence the consideration of this issue. Firstly, the dominance of agriculture in New Zealand's economy. Secondly, agricultural production is underpinned to a large extent by phosphate fertiliser, the major source of cadmium into agricultural soils. The third issue is the importance of the international trade to New Zealand agriculture and economy, which depends in turn on factors such as consumer demand, international regulation, and the wider economic and geopolitical situation.

In order to assess and mitigate any risks associated with cadmium, the Chief Executives' Environment Forum established a Cadmium Working Group, to investigate and assess the potential risks surrounding cadmium in New Zealand's agriculture and food systems, and to develop responses as required.

There are two basic approaches to assessment of cadmium: a 'risk based' approach and a 'mass balance' approach. The Cadmium Working Group used and promotes a risk based approach.

Chapter 2: Current management approaches for cadmium in New Zealand

In New Zealand, there are systems currently in place to manage the different risks from cadmium levels in soils, food, and phosphate fertiliser.

There are currently no national-level standards for the permissible amount of cadmium in agricultural or residential soils or for the discharge of cadmium onto soil in New Zealand. There are a variety of guidelines (some developed in New Zealand and others overseas) which councils may use to guide them in this assessment. These guidelines are not legally binding, unless councils give them legal effect by incorporating them into a regional or district plan, or as a condition on resource consents.

The Ministry for the Environment has published a 'guideline to the guidelines' called the Contaminated Land Management Guidelines 2 (CLMG#2), which sets out a process for councils to follow for selecting an appropriate guideline value for use in a contaminated site assessment.

The end-result of this regulatory environment is that, following the process set out in the CLMG#2, values currently used by some councils to indicate the requirement for a contaminated site assessment or to determine whether a site should be identified as contaminated on a LIM (Land Information Memoranda) or PIM (Project Information Memoranda) report issued under the Local Government Information and Meetings Act 1987 for cadmium range from 1 mg/kg (residential soils) to 22 mg/kg (industrial soils) depending on land use. The guideline value applicable to a particular land use has the potential to have significant consequences for landowners and their land-use choices. Guidelines should make reference to soil sampling depth and sampling method, in order to ensure that there is consistency. Analytical methods should also be stipulated, to ensure comparable results.

At the industry level, there has been a voluntary initiative by the fertiliser industry to limit the amount of cadmium present in phosphate fertilisers, which is discussed further in Chapter 3.

New Zealand Food Safety Authority (NZFSA) and the Food Standards Australia New Zealand (FSANZ) jointly manage food safety, including monitoring the levels of heavy metals such as cadmium in the diet.

Chapter 3: Summary of current information on soil cadmium levels, inputs, and uptake by plants and animals

Cycling of cadmium in agricultural systems: from pasture to plate

There has been a steady increase in the amount of phosphate fertiliser used in New Zealand to a high of over two million tonnes in 2002/03 (or 220,900 tonnes expressed as the elemental phosphorus content). Over the last five year period (2001-2005), approximately 30 tonnes per annum of cadmium were added to New Zealand's agricultural soils through phosphate fertiliser use.

Historically, New Zealand has sourced its phosphate rock from Nauru, which was very high in cadmium relative to other phosphate rock sources, averaging about 450 mg Cd/kg P. In 1995, the superphosphate manufacturers embarked on a cadmium reduction programme which resulted in the phasing out of the Nauru supply. A voluntary industry limit for cadmium content in phosphate fertiliser of 280 mg Cd/ kg P was imposed. The limit has been consistently bettered, over recent years. From 2001-2005, the weighted average content of cadmium in phosphate fertiliser was about 180 mg Cd/kg P.

There is currently no cost-effective or practical method of removing cadmium from phosphate rock. Low-cadmium containing phosphate rock is either unavailable or difficult and more expensive to source.

The cycling of cadmium through agricultural systems is complex, and influenced by many factors. The amount of cadmium present and soil conditions including acidity (pH), organic matter, and soil salinity, can increase the amount of cadmium taken up by plants. The availability of cadmium is increased by soil acidity and decreased by the presence of organic matter in soils.

Plant-related factors that influence the uptake of cadmium include: the crop species and cultivar; the types of plant tissue; leaf age and metal interactions. Generally, cadmium is stored in leaves more than in roots, seeds and fruit.

Animals can take up cadmium from ingesting fertiliser directly, through soil uptake during grazing or as a result of eating pasture plants containing cadmium. Of these, the intake of cadmium via pasture is the most significant on average. Cadmium accumulates in the kidneys and livers of grazing animals over time, and so increases in these organs as animal's age.

Cadmium levels in NZ soils

Based on an analysis of conservation estate and other non agricultural soil samples from various studies, New Zealand has a national average baseline (i.e. the 'natural' background level in soils) value for cadmium of 0.16 mg/kg, consistent across all regions and soil types. The current national average concentration for cadmium across all agricultural land classes is 0.35 mg/kg (mean of all samples) with a range of 0-2.52 mg/kg.

The cadmium content of agricultural soils will vary from region to region depending on history of phosphate fertiliser use, dominant land use, soil type, climate, sampling depth and bulk density.

Land-use is a key driver of topsoil cadmium concentrations. Cropping, pasture and horticulture land-uses all have higher concentrations of cadmium in soil than background, 'natural' land. The reason for this is almost certainly the application of phosphate fertiliser in most agricultural and horticultural land use.

Land used for dairying has the highest national average for cadmium concentration (0.73 mg/kg). Kiwifruit (0.71 mg/kg), berries (0.68 mg/kg), orchards (0.66 mg/kg), market gardens (0.46 mg/kg), beef farms (0.42 mg/kg) and unspecified drystock pasture (0.40 mg/kg) were also above the national average. Cropped soils appear to be mostly below the national average of 0.35 mg/kg for cadmium; however, these soils are tilled to a greater depth (20 cm) than other land-uses, and dilution decreases the cadmium concentration. Soils where tobacco was grown in the past were more elevated in cadmium (0.34 mg/kg) than other cropping soils. Sheep farms were slightly below (0.33 mg/kg) the national average. Sites receiving little or no fertiliser had the lowest cadmium concentrations (unfertilised 0.19 mg/kg, plantation forestry 0.14 mg/kg, native forest 0.10 mg/kg).

Results from the analysis of national data were broken down to regional council regions. The region with the highest average cadmium concentration was Taranaki (0.66 mg/kg). Other regions with similar cadmium concentrations include Waikato (0.60 mg/kg) and Bay of Plenty (0.52 mg/kg). Dairy farming with a historically higher use of phosphate fertiliser is traditional in these areas and the soils of these regions have a high propensity to accumulate cadmium according to the Fertiliser Manufacturers' Research Association (NZFMRA) cadmium model. The regions with the lowest cadmium average concentrations were Canterbury (0.17 mg/kg), Gisborne (0.20 mg/kg), Manawatu-Wanganui (0.17 mg/kg), Nelson-Marlborough (0.23 mg/kg), Otago (0.20 mg/kg) and Southland (0.21 mg/kg) and Wellington (0.20 mg/kg), all historic sheep farming areas.

Projections of future soil cadmium levels

An initial estimation of future topsoil cadmium concentrations was carried out using the Fertiliser Manufacturers' Research Association CadBal model and the national data summarised above. Results showed Brown Grey Clay Loams, Yellow Brown Loams and Yellow Brown Podzols soils accumulated more cadmium than the other soil types while alluvial, Yellow Brown Earths and Yellow Grey Earths soils accumulated the least cadmium. Differences in soil type cadmium accumulation appear due to differences in leaching losses and soil bulk densities input to the model.

In the model, sampling depth was related in an inverse relationship to cadmium concentrations. For example, increasing the sampling depth from 0–7.5 to 0–10 to 0–20 cm was shown to reduce the cadmium concentration from 0.43 mg/kg to 0.37 mg/kg to 0.26 mg/kg for a Yellow Brown Earth under dairy farming receiving 30 kg P $ha^{-1}y^{-1}$.

The model also showed pastoral farming resulted in increased soil cadmium content in all regions and nationally. The peat soils of the Waikato region showed the highest potential for cadmium accumulation - although this could in part be due to the low bulk density of these soils not being taken in account in the model. The regions with the highest present-day soil cadmium content also have the highest potential to accumulate cadmium in the future. Sheep/beef farming led to more accumulation of cadmium than dairy when both are under the same fertiliser regime although, in practice dairy farming requires more fertiliser for optimal production than beef and sheep farming. The difference in potential accumulation was due to the difference in the rates of soil loss (sedimentation loss) - 900 kg ha^{-1} y^{-1} for dairy farming and 500 kg ha^{-1} y^{-1} for sheep and beef. However, sedimentation losses are due to a range of factors including topography, soil type, leaching class and climate, not just farm type, and this result is questionable.

Model predictions of cadmium levels in soils under dairy farms were shown to decrease in cadmium with time once soil cadmium exceeded about 1.3 mg kg^{-1} due to removal of sediment, erosion products and leaching. This result is thought to be an artefact of the model or uncertainty in input values for leaching and erosion, but if validated by empirical observation, may have important implications for farm sustainability and its accuracy should be further investigated.

Historically, the average rate of cadmium accumulation in New Zealand soils is estimated to be 6.6 µg/kg/yr. Loading estimates (allowing for losses) suggest that the current accumulation rate may be about two thirds of this figure, or 4.3 µg/kg/yr. Such a reduction would be consistent with the effect of the voluntary industry limit for cadmium in phosphate fertiliser of 280 mg/kg P, which was introduced from 1997.

Chapter 4: Assessment of risk to human health

Dietary cadmium can lead to both chronic and acute adverse health impacts, depending on the levels consumed. The New Zealand Food Safety Authority monitors and manages the levels of contaminants in the diets of New Zealanders. The Provisional Tolerable Weekly Intake (PTWI) is commonly used to measure dietary exposure to cumulative contaminants such as cadmium, and represents a level of a substance which can be consumed on a weekly basis over a lifetime with no appreciable risk.

It is the New Zealand Food Safety Authority's assessment that the cadmium dietary exposures found in the 2003/04 New Zealand Total Diet Survey (NZTDS) are highly unlikely to have any adverse health implications for the New Zealand population. The estimated weekly intake of all age-sex groups surveyed was well below the PTWI and has generally been decreasing since 1982.

Cadmium levels found in the food products surveyed were generally consistent with internationally documented levels (WHO, 1992a; Jensen, 1992). Oysters were a significant contributing source of cadmium in those simulated diets which included oysters. Other food products which contributed significantly to the overall weekly dietary cadmium intake were bread and potatoes.

As most non-smokers' main exposure to cadmium is through food, and since the level of exposure to cadmium through food in the average New Zealand diet (as measured in the 2003/04 NZTDS) is highly unlikely to cause health impacts, it can be concluded that cadmium levels in foods currently do not pose a risk to human health in New Zealand.

Chapter 5: Assessment of risk to export trade and economy

The potential of cadmium accumulation in agricultural soils to pose a risk to New Zealand's export trade is examined in this chapter. If cadmium accumulated in soils to levels at which food produced on those soils began to breach food safety standards, both domestic and export sales of these food products - could be compromised. New Zealand agricultural products for export must meet domestic food standards, and also those of export markets, which could be more stringent.

In the short term the risk to the New Zealand economy is *low.* Any risks from significant accumulation of cadmium fall on a relatively small segment of the agriculture sector; mainly leafy vegetable producers and offal from animals. Dairy (milk), muscle meat and fruit products are unlikely to be at risk of high cadmium levels, due to the low capacity of these products to store cadmium. The New Zealand Food Safety Authority currently has a process in place that manages the risk posed by offal's containing high levels of cadmium.

Besides the direct low risk of exceeding food standards for cadmium in offal and some vegetables, there are also more 'indirect' risks, such as the possibility of New Zealand's standards for cadmium in soil or fertiliser falling behind those of our trading partners, with subsequent damage to our ‘clean and green’ reputation. These indirect effects could be played out in the private sector, for example, through large international food retailers which are increasingly insisting on more stringent standards for food safety, environmental performance and animal welfare as commercial conditions.

It would be useful to consider ways to mitigate these risks for producers who produce the small subset of commodities which could potentially be affected by cadmium accumulation in soil.

Chapter 6: Assessment of risk to land use flexibility

There are two main adverse impacts on land use flexibility which could occur from cadmium accumulation:

1. Cadmium accumulation in agricultural soils could affect the future ability to subdivide the land for residential or rural-residential purposes without some form of rehabilitation. In New Zealand, a substantial portion of new residential housing development takes place over agricultural (pastoral and horticultural) land, which is often moderately elevated in cadmium due to use of phosphate fertilisers. While such land is unlikely to pose any immediate human health risks, it may exceed a guideline value for acceptable cadmium levels in soils, depending on the soil guideline value relevant to intended land use.

   This problem would mostly affect those with land that had received ongoing applications of phosphate fertiliser (e.g. dairy), that was close to the perimeter of an urban area and who wished to subdivide their land into residential blocks.

2. If cadmium in agricultural soils built up to significant levels over time, this could affect the ability of landholders to grow certain types of agricultural products, due to the cadmium levels in these products exceeding food standards, or best-practice requirements set by overseas markets (such as EUREPGAP - Euro Retailer Produce Working Group).

   This problem could affect people wishing to convert from a land use which had required ongoing phosphate fertiliser application (e.g. dairy or pastoral) to growing a horticultural crop which was sensitive to cadmium levels in the soil. It could also affect those wishing to switch from growing fruit crops to vegetables, if the land had received significant phosphate application whilst growing fruit.

The two different land-use flexibility issues require different responses. The first type of risk stems from some uncertainty over how regional councils should best assess and approach the issue of cadmium, and other contaminants, in soils. It could be addressed through the development of a National Environmental Standard. This approach would provide a unified national approach standard.

The second type of risk needs to be managed through improved monitoring of cadmium levels in soils, crops and animal offals, providing information to farmers and growers, ensuring that the standards used to assess safe levels of cadmium in food are interpreted and applied in a consistent and science-based manner, and, where appropriate, on-farm management techniques such as deep-ploughing or liming to manage cadmium levels in soils. However, these management methods are only a temporary solution and ongoing monitoring of soil chemistry would be required.

Chapter 7: Conclusions and recommendations

Overview

The Cadmium Working Group has found that the risks from cadmium are currently not acute. However, as phosphate fertiliser use is likely to continue, or increase in future, current trends will lead to ongoing cadmium accumulation in New Zealand soils. This means the issue needs to be actively monitored and managed, with a strategy developed to mitigate and manage these risks.

The issues relating to cadmium accumulation in soil ultimately come down to the potential for risk to human health and the environment. The other risks (impacts on our export trade and ability to change land use) are in fact secondary risks which arise from the operation of regulatory limits for cadmium in food and soils which are put in place primarily to protect human health. Although regulatory limits may only semi-quantitatively relate to human health, they still have their own currency and force.

The areas of risks investigated in this report all stem from a primary concern over human health impacts. If human health based standards/limits are exceeded, then there are flow on effects such as the economic impacts on trade, potentially losing agricultural markets due to high cadmium levels, or constraints on land-use flexibility due to breaching soil guideline values are both issues that stem from regulatory systems designed to protect human health. There is a need to not only monitor and manage the levels of cadmium in soil, but also to ensure that the domestic and international regulatory system protecting human health through food standards or land use policies and plans are appropriate, and applied according to consistent and science based processes.

The Cadmium Working Group recommends that

- Cadmium accumulation in agricultural soils be recognised as an emerging issue, with local and central government committing to giving it ongoing attention.
- A national cadmium strategy should be developed supported by all stakeholders in order to mitigate future risks from cadmium.
- Policy direction is provided by accountable national policy agencies as to the preferred New Zealand model for managing risks to sustainability, posed by cumulative heavy metal contaminants in agricultural soils: either the no net accumulation or risk-based approach (which usually permits some accumulation up to a set threshold or investigation trigger level).
- The national cadmium strategy is developed with particular attention to, and consultation with the horticulture and grain sector.
- The meat industry should assess the ongoing suitability of current risk management practices for meat products such as offal’s in line with a national cadmium strategy.
- The Ministry for the Environment gives greater guidance to local authorities, in order to ensure that cadmium levels are assessed and evaluated in a consistent and appropriate manner. This guidance could be in the form of a National Environmental Standard on the assessment and evaluation of cadmium in soils under a variety of land uses, possibly with a tiered approach in which soil cadmium levels are linked to specific management action(s).
- A national monitoring programme is established for ongoing fertiliser, soils, plant and animal cadmium levels assessment. This is needed for meeting the regulatory

requirements of a number of organisations. This programme should include the following features:

    - Nationally consistent methods and protocols for collection, sampling and analysis of cadmium e.g. soil sample depth and number, in order to allow for comparison of results.
    - Timely updating of monitoring data on cadmium levels, at least every 5 years.
    - Greater co-ordination between organisations in collecting and providing data on cadmium levels locally and nationally.
    - Determine the impact on cadmium levels of farming practices or land uses e.g. zinc use.

- The New Zealand Food Safety Authority assess the need to undertake a comprehensive food survey of cadmium in vegetables, wheat grain, liver and kidney, in order to:
    - better determine the population distribution of cadmium in each food type, and
    - more reliably determine the actual rates of persistent non-compliance with food standards.
- New Zealand officials approach Food Standards Australia and New Zealand for a discussion on:
    - appropriate interpretation of the joint food standard for cadmium in wheat; and
    - what, if any; 'background rate' of non-compliance in vegetables would be regarded as tolerable; and
    - prospects for enhancing the Australian and New Zealand food standards to accommodate special features of the population distribution of cadmium in selected foods.

Next steps

The Cadmium Working Group believes that a further report needs to be developed that will investigate and assess a range of possible options to control the build up of cadmium in New Zealand. Based on the issues raised in this report, the options in the next report should focus on exploring:

1. the role of national standards and/or guidelines for soil cadmium levels, including the intersection of the cadmium issue with Ministry for the Environment's work on National Environmental Standards and the usefulness of a national policy or standard for soil cadmium;
2. the standardisation of sampling and analytical procedures, protocols and methodology for cadmium using established national and international methods and standards;
3. where current management activities can be strengthened or directed towards the strategic risks and information gaps identified in this report. For example; whether the New Zealand Food Standard Authority should study produce from home gardens; whether regional council soil monitoring can focus more attention on cadmium; whether consideration be given to differentiating between total and bio-available cadmium;

4. the potential economic costs associated with reducing cadmium inputs to soil, and whether they outweigh the benefits of mitigating the risks;
5. opportunities for increased investment in technology to reduce cadmium levels in phosphate rock;
6. farmer education on cadmium issues, including whether existing fertiliser codes of practice should include more guidance on cadmium;
7. identification of on-farm management practices to mitigate risks to horticulture and agriculture; and
8. the indicative content of a National Cadmium Management Strategy and any governance arrangements, building on international experiences.

Chapter 1: Setting the context - an introduction to the cadmium issue

Background to the Cadmium Working Group

The issue of cadmium in agricultural soils is not new, or unique to New Zealand. Since 1990, approximately forty peer-reviewed papers have been published in the scientific literature which examines aspects of cadmium in New Zealand agriculture. However, recent interest in the topic was sparked by an Environment Waikato report looking at cadmium levels in agricultural soils in the Waikato region.

Subsequently, it was considered appropriate to conduct a wider 'stock take' of the cadmium issue at a national level. Further work was necessary to estimate the extent of cadmium accumulation in New Zealand agricultural soils, and to assess the likelihood and magnitude and consequences of any ensuing risks.

At a meeting in May 2005 of the Chief Executives' Environment Forum[1], a grouping of chief executives from central and local government supported a proposal to establish a Cadmium Working Group, with membership from central and local government, and representatives from industries directly affected by the issue. The group was charged with undertaking updated cadmium 'stock take', to explore the issues and risks relating to cadmium in New Zealand agriculture and food systems, and to develop and assess policy options for managing any risks.

The Cadmium Working Group's *Terms of Reference* require the production of two reports (of which this is the first).

The first report would scope, at a national level:

- the extent of cadmium accumulation throughout the country; including source and sinks.
- the variation between different regions, types of agriculture;
- the implications of such accumulation for trade, future soil use and other issues deemed relevant;
- the issue of appropriate national standards and existing guidelines for cadmium in agricultural soils, noting the current responsibilities for standard setting of public bodies such as the Ministry for the Environment and New Zealand Food Safety Authority;
- an assessment of the risks and implications.

The second report is to be a solutions report, outlining policy options to address the issue. This report would consider appropriate options for management of cadmium, and provide an assessment of these options.

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1 The Chief Executives Environment Forum is a group of chief executives from regional government and central government departments that have strong interests in environment and resource management - Environment, Agriculture and Forestry, Economic Development, Fisheries, Conservation, Transport, Internal Affairs, State Services Commission, Department of Prime Minister and Cabinet, and Te Puni Kokiri. The forum is convened by the Ministry for the Environment, and meets four times a year to exchange information and views, plan joint work programmes, agree on complementary activities, and resolve problems. (source: MfE website, http://www.mfe.govt.nz/publications/about/briefing-oct05/html/page3.html, accessed September 2006).

Membership of the Cadmium Working Group

The cadmium working group comprises senior representatives from the following organisations.

Horticulture New Zealand

Horticulture New Zealand is an alliance of the former NZ Fruitgrowers' Federation, the NZ Vegetable and Potato Growers' Federation and the NZ Berryfruit Growers' Federation, which now represents 7,000 commercial fruit and vegetable growers. It aims to provide strategic leadership, raise the industry's profile, to advocate on behalf of the horticulture sector and address issues which impact on business.
http://www.hortnz.co.nz/

Dairy Insight

Dairy Insight co-ordinates and funds 'industry good' activities on behalf of all dairy farmers, who pay a levy based on a percentage of their milksolids production. Dairy InSight's focus is on providing industry leadership, in order to help make dairy farming more profitable and sustainable in the future.
www.dairyinsight.co.nz

Fonterra

Fonterra is a leading multinational dairy company, owned by 11,600 New Zealand dairy farmers. It is the world's largest exporter of dairy products, exporting 95 percent of its milk production. Fonterra also manufacturers and markets a vast range of dairy products and ingredients, which are sold in 140 countries around the world, and funds research and advocacy for the dairy sector.
www.fonterra.com

Meat & Wool New Zealand

Meat & Wool New Zealand is an industry body, funded by livestock and wool producers through levies. It promotes New Zealand red meat internationally and domestically, advocates for the extension of trade access for New Zealand wool and red meat; funds research and development, and provides wool technical advice.
http://www.meatandwoolnz.com

New Zealand Fertiliser Manufacturers' Research Association (Fert Research)

Fert Research funds research into fertiliser and agriculture, liaises with a range of groups including government, regulatory bodies, industry, and research organisations, and also provides information on fertiliser use and nutrient management.
http://www.fertresearch.org.nz

Environment Waikato (EW), Environment Canterbury (ECAN) and Greater Wellington (GW)

These are regional councils, established under the Resource Management Act 1991. Regional Councils are responsible for environmental management and planning in their regions, including the management of the effects of use of freshwater, coastal waters, air and land, biosecurity, river management, regional land transport planning and civil defence.
http://www.ew.govt.nz/; http://www.gw.govt.nz/; http://www.ecan.govt.nz/

Ministry of Agriculture and Forestry (MAF)

The Ministry of Agriculture and Forestry informs, advises, regulates and delivers services relating to the agriculture, forestry, rural affairs, biosecurity and food safety portfolios. MAF's mission is to enhance New Zealand's natural advantage. MAF does this by: encouraging high-performing sectors; developing safe and freer trade; ensuring healthy New Zealanders; and by protecting our natural resources for the benefit of future generations.
http://www.maf.govt.nz

New Zealand Food Safety Authority (NZFSA)

The New Zealand Food Safety Authority (NZFSA) administers legislation covering food for sale on the New Zealand market, primary processing of animal products and official assurances related to their export, exports of plant products and the controls surrounding registration and use of agricultural compounds and veterinary medicines. NZFSA is the New Zealand controlling authority for imports and exports of food and food-related products.
http://www.nzfsa.govt.nz

Ministry for the Environment (MfE)

The Ministry for the Environment is the Government's principal adviser on the New Zealand environment and international matters that affect the environment. MfE has taken a central role in developing policy relating to contaminants in the environment, and developed a series of best-practice guidelines to assist local authorities and environmental consultants in the management of contaminated land.
http://www.mfe.govt.nz

The Cadmium Working Group's approach to risk assessment

The Cadmium Working Group's first report is essentially a risk assessment. Risk assessment is a systematic evaluation of a particular risk, which is then used to inform decisions around what kinds of actions, if any, are needed to manage the risk. It seeks answers to the question: "*how likely is it that damage will be or has been done by the hazard?*"

Risk assessment is one component of the larger process known as risk management. The risk assessment provides the crucial information on which decisions about how to manage the risk can be made. The likelihood of adverse impacts on people, the environment or the economy, will inform decisions on whether intervention is required, and if so, what kinds of intervention. This stage of risk management is when policy considerations come into the process.

The social, economic, political context will usually be considered when assessing risk management options and value judgments may be made. The magnitude of the risk can be weighed against other considerations, such as the benefit from the activity generating the risk, social and political acceptability, and the cost effectiveness of treatment options.

The second report will correlate to the stage of 'risk management option assessment', in which policy options to treat or manage the risk are evaluated.

The scope of the Cadmium Working Group's risk assessment

The Terms of Reference state that the Group's risk assessment is to consider the risks *from cadmium in agricultural soils, to New Zealand agricultural and food systems.* 'Agricultural systems and food systems' is taken to encompass export trade and also future land use flexibility, as these are integral considerations to New Zealand agriculture.

In terms of potential human health impacts from cadmium, this report focuses on the dietary intake of cadmium. This is because the main exposure of the general populace to cadmium is in the diet. Specific, localised risks to small sectors of the population, such as occupational safety and health risks are not considered in this report.

Very little is known about the potential environmental impacts of cadmium accumulation. Monitoring of groundwater and freshwater has not shown evidence of increasing cadmium levels. However, very little monitoring for cadmium in water is carried out. It is possible that cadmium inputs to soil from fertiliser could accumulate in receiving freshwater sediments. The environmental impacts of cadmium in broader natural ecosystems are outside the scope of this report.

Cadmium in brief

Cadmium is a naturally-occurring, non-essential heavy metal which is present at low concentrations in air, water and soils. Cadmium has uses in industrial production, and is also present as an impurity in some non-ferrous metals (zinc, lead and copper), iron and steel, fossil fuels, cement and phosphate fertilisers.

Cadmium levels in the environment vary widely. Cadmium cycles in the environmental between air, water, soils, living organisms, sediments, rocks and minerals. In surface environments and over human timescales, air and water act as transport routes for cadmium, whereas soils and sediments act as cadmium sinks.

Air

Natural sources of cadmium to the atmosphere include forest fires, volcanoes, sea-salt spray, and wind-borne soil particles. Cadmium is present, therefore, in background ‘ambient’ air, as well as in higher levels in air carrying industrial emissions or cigarette smoke. Globally, the main anthropogenic sources of cadmium emissions to the atmosphere are non-ferrous metal production, waste incineration and fertiliser manufacture (Nriagu, J O and Pacyna, J M, 1988).

Soil

In soils, cadmium originates from both natural and human-derived sources. Natural sources include the underlying bedrock or parent material. Human-derived inputs of cadmium to soil include the application of sewage sludge, manure and phosphate fertiliser. Anthropogenic discharges of cadmium to the atmosphere also contribute to cadmium levels in soil, as the cadmium settles onto land and water. In heavily industrialised parts of the world, cadmium in the atmosphere is often a significant source of cadmium input into soil. In New Zealand, the main source of human-derived cadmium to agricultural soils is phosphate fertiliser (Roberts et al, 1997).

Water

Cadmium exists naturally in small amounts in both freshwater and in the oceans. Cadmium may enter aquatic systems through weathering and erosion of soils and bedrock, atmospheric deposition, direct discharge from industrial operations, leakage from landfills and contaminated sites, and the leaching of fertilisers and biosolids from agriculture.

Cadmium and health

Cadmium can have adverse effects on human health, at high levels of exposure over a short period (acute exposure), or at low levels over a long period (chronic exposure). Most exposure of New Zealanders to cadmium occurs through low-level concentrations of the metal in food, or cigarette smoking. Cadmium accumulates in the bodies of animals, including humans, and so the amount of cadmium stored in the body increases with age. However, the New Zealand Food Safety Authority has estimated the amount of cadmium in the diet of the average New Zealander is at a level far below that which would cause adverse health effects (Vannoort; R W & Thomson, B M. 2005) (this is discussed in more detail in Chapter 4).

Agriculture, fertiliser and New Zealand's economy

Agriculture and New Zealand's economy

More so than most other developed countries, New Zealand's land-based sectors are strongly export orientated, have very low import protection, and are not supported by export or production subsidies (MAF, 2005b). Therefore, the fortunes of New Zealand's agriculture are very much subject to conditions in international markets.

New Zealand's economy relies heavily on agriculture[2], it is the largest export earner, which earns 52% of the country's total merchandise export value (year to June 2004). The total gross revenue from the agriculture sector, from the year ended March 2004, was estimated at $16.8 billion. This equates to about 13% of New Zealand's Gross Domestic Product. Agriculture is also a growing industry; by 2008 the total gross revenue earned by the sector is projected to increase by about 9%, to $18.3 billion (MAF, 2005b).

The agricultural sector is the only major industry in New Zealand with world class economies of scale, global market reach, and world leading technological capabilities. New Zealand is the world's largest exporter of dairy products, sheep meat and venison, second in kiwifruit, a major player in apples, and the fourth largest beef exporter (MAF, 2005). All this means that agriculture is a major driver of the New Zealand economy, fuelling many other businesses, such as manufacturing and processing and indirectly contributing to the retail and service sectors.

Agriculture dominates land use in New Zealand, as it does in many other countries globally. Most New Zealand agriculture is based on extensive pasture systems with animals grazed outdoors all year round. Between 1986 and 2002, the total amount of land farmed as dairy farms increased by 47%, reflecting the high economic returns from dairy in recent years. There are now approximately 2 million hectares (out of a total land area of 27 million hectares) under dairy farming in New Zealand (Statistics New Zealand, 2006, p 5). The area in sheep and beef farming has declined over the same period, and in 2002 stood at about 10.3 million hectares (ibid). The area under horticulture has expanded rapidly over the last fifteen years, but occupies about 1% of all land in agricultural use.

Fertiliser and agriculture

New Zealand's soils tend to be naturally low in the four major nutrients required for plant growth: nitrogen, phosphorus, potassium and sulphur. As a result, on most soils, high levels

2 Agriculture is defined here as including both on-farm production and first-stage processing of food and fibre. Horticulture is a component of agriculture.

of plant growth can only be achieved and maintained with nitrogen-fixing legumes (such as clover) and significant inputs of fertilisers. In some areas, planted forests are also bolstered with fertiliser. It is estimated that without the extra soil nutrients provided by fertiliser, New Zealand's soils would only be able to support between 25 and 50% of the current number of animals grazed or crops grown (Statistics New Zealand, 2006). In other words, fertiliser use underpins a significant proportion of New Zealand's economic production.

Dairy farming requires significantly more fertiliser per unit area than most other animal production land use types, because milk production depends on intensive grazing on high yielding pastures, which are maintained by inputs of fertiliser. Therefore, the trend towards converting land to dairy from other uses is contributing to growing rates of fertiliser use.

Phosphorus is an essential element for plant and animal nutrition. Cadmium is present as a naturally-occurring contaminant in phosphate rock, from which phosphate fertilisers are made.

New Zealand has no natural reserves of phosphate rock, and so all phosphate is imported largely from Morocco. The cadmium levels in phosphate rock vary widely depending on the source location. Worldwide, sources of low-cadmium phosphate rock are very limited and not currently available to New Zealand manufacturers.

New Zealand's geography and geology

An important part of the New Zealand context is this country's geography, geology, and the properties of the soil itself. These natural conditions influence the way in which cadmium accumulates, and becomes available for uptake by plants and consumed by animals and humans. Chapter 3 of this report reviews the current scientific literature on the interactions between natural conditions and other factors, which influence the bioavailability of cadmium to humans, plants and animals.

In general, the soils of New Zealand differ significantly from those of Europe and North America. Soil types in New Zealand are considered very diverse, despite the small size of the country (McLaughlin *et al*, 2000). New Zealand soils are geologically young and therefore less weathered, and have relatively high organic matter contents compared to similar soils in most other countries (ibid). Variable charge minerals (mainly hydrated oxides of iron and manganese) form an important component of many New Zealand soils, whereas in North America and Europe, many soils are dominated by permanent charge minerals (e.g. clays) (ibid).

Many New Zealand soils are also classified as being highly acidic. Soil acidity, the nature and type of adsorptive phases in a soil, and presence or absence of competing elements (such as zinc) or complexing agents (such as fulvic acid) all play a role in determining how cadmium will behave in the environment, and therefore, the ease with which it may enter the food chain. Due to low-cadmium phosphate being used in the US, accumulation of cadmium from fertilisers does not appear to pose such an issue in the US as in Australia, New Zealand, and parts of Europe (McBride and Speirs, 2001).

The New Zealand climate is also highly variable, which again influences the behaviour of metals in soil, and therefore accumulation rates and bioavailability. Rainfall and temperature vary markedly between different parts of the country.

Chapter summary

Cadmium is a naturally-occurring, non-essential heavy metal which is present at low concentrations in air, water and soils. Both acute and chronic cadmium exposure can have adverse health effects on people. In New Zealand, industrial exposure to cadmium is rare, and so the main source of cadmium for New Zealanders is in tobacco products or food. Low levels of cadmium in the diet can accumulate over a person's lifetime to reach levels at which they may begin to affect health. The New Zealand Food Safety Authority has estimated the amount of cadmium in the diet of the average New Zealander is at a level far below that which would cause adverse health effects.

Phosphate fertilisers contain cadmium as a trace impurity and cadmium tends to accumulate in soil with repeated application of phosphate fertiliser. Accumulation rates in soils will vary between regions of New Zealand due to differences in land use history, phosphate fertiliser cadmium content, total fertiliser use, soil types, climate, and a number of other variables. Cadmium can cause adverse animal and human health impacts at high levels or at lower levels if exposure occurs over a prolonged period.

There are three key threads to the New Zealand context relating to cadmium in soils, which influence the consideration of this issue. Firstly, the dominance of agriculture in New Zealand's economy. Secondly, agricultural production is underpinned to a large extent by phosphate fertiliser, a major source of cadmium into agricultural soils. There is currently no cost-effective or practical method of removing it. Low-cadmium phosphate rock is either unavailable or difficult and more expensive to source. The third issue is the importance of the international trade to New Zealand agriculture and economy, which depends in turn on factors such as consumer demand, international regulation, and the wider economic and geopolitical situation.

In order to assess and mitigate any risks associated with cadmium, the Chief Executives' Environment Forum established a Cadmium Working Group, to investigate and assess the potential risks surrounding cadmium in New Zealand agriculture and food systems, and to develop responses as required.

There are two basic approaches to assessment of cadmium: a 'risk based' approach and a 'mass balance' approach. The Cadmium Working Group used and promotes a risk based approach.

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Chapter 2: Current management approaches for cadmium in New Zealand

General approaches to the management of soil contaminants

Mass balance vs risk-based approaches

There are two approaches that are commonly used to ensure the safe management of contaminants; the ‘mass balance’ approach or the ‘risk-based’ approach. These two approaches have quite different philosophical underpinnings, and can result in different management regimes.

Mass balance approach

Some northern European countries aim to minimise or avoid any accumulation of heavy metals stemming from human activities. This method generally uses mass-balance modelling, synthesising information on heavy metal inputs and outputs, to find a level of input which can be applied over time without causing net accumulation (Molloy et al, 2005). In effect, this approach aims to maintain background or current heavy metal concentrations indefinitely, unrelated to any perceptions of the risk attributable to the base level of the contaminant.

Countries which have used this approach, such as Sweden, Norway and Denmark, also tend to favour stricter standards for the permissible levels of various metals in sewage sludge (Renner, 2000).

Risk based

Other countries have set standards for the inputs of metals into soil by taking a risk-based approach. This method, rather than trying to avoid any build-up of metals, aims to determine the levels of metal in soils which represents an acceptable risk (Renner, 2000). Often this approach will determine the level at which adverse impacts are observed (on the environment or to human health, or both), and then set a soil concentration limit or trigger level below this level, allowing for a safety margin (ibid).

Examples of countries that use risk-based methodologies to determine safe levels of contaminants in soils include the United States, Australia under National Environmental Protection (Assessment of Site contamination) Measure (1999) for human health protection, the United Kingdom and the Netherlands (Renner, 2000).

The mass-balance and the risk-based methods have different advantages and disadvantages. The risk based approach can involve a significant level of uncertainty (knowledge of ecological systems and interactions has many significant gaps) and subjective judgment and assumptions (deciding whether risk to people, animals, plants, or entire ecosystem function should be considered, as well as deciding what constitutes ‘acceptable’ risk) and can produce varied results. The ‘no-net-accumulation’ approach, on the other hand, can be unnecessarily restrictive, as it can peg input levels (from fertiliser, biosolids or manure) at levels far below what would begin to pose a risk to people or ecosystems. If this is the case, land managers are effectively burdened with costly restrictions beyond what is appropriate to ensure safe agricultural practices.

Approach taken by the Cadmium Working Group

This report takes a 'risk-based' approach to its examination of cadmium accumulation in agricultural soils (the second report will focus on an evaluation of risk management options).

The risk-based approach fits with New Zealand's environmental management framework, as set out by the 'effects-based' Resource Management Act 1991. The Ministry for the Environment's contaminated land management guidelines which provide guidance to regional councils on selection and applying environmental guideline values (i.e. soil limits) also advise taking a risk-based approach to setting guideline values. Guideline number two (Hierarchy and Application in New Zealand of Environmental Guideline Values (MfE 2003)) provides guidance to all organisations on selecting contaminated site assessment guideline values. Food safety administration in New Zealand is moving towards a risk-based approach to food safety management, in line with international trends (FAO, 2004).

It is appropriate that the management of cadmium in soil be based on "risk assessment", rather than taking the 'no-net-accumulation' approach. If inputs exceed outputs then a risk based approach will result in soils cadmium eventually reaching a specified guideline value and a mass balance approach will need to be adopted at that stage.

New Zealand's management of cadmium in, or relating to, agricultural systems is obscure, relying on a range of central government legislation, guidelines and local government controls. Central and local government have developed these measures to protect the environment, including the health and well-being of people and communities.

Current management of contaminants in New Zealand

The Resource Management Act

The Resource Management Act 1991 (RMA) is the core piece of legislation controlling how our use of the environment is managed. The RMA contains defines 'contaminated land', requires planning controls to manage the discharge of hazardous substances and effects of these substances in or on land. The RMA also defines functions for local government in relation to contaminated land. Under the RMA, the bulk of decision-making authority rests with local government.

Definition of contaminated land

Contaminated land is defined in section 2 of the RMA as land that has hazardous substances[3] in or on it and:

1. is more contaminated than an applicable National Environmental Standard,[4] or
2. has, or is reasonably likely to have, significant adverse effects on the environment.

While cadmium on its own may be classed as a hazardous substance, fertiliser containing cadmium is not.

3 The RMA section 2 definition of "hazardous substance" includes, but is not limited to, any substance defined in section 2 of the Hazardous Substances and New Organisms Act 1996 as a hazardous substance.

4(a) does not currently apply as there are no national environmental standards for contaminants in soil at the time of publication of this report.

Discharges

While fertiliser is not a hazardous substance, it is generally considered a “contaminant” as defined under the RMA. The discharge of “contaminants” requires resource consent under section 15 of the RMA unless permitted by a rule in a plan. Regional plans generally have a rule permitting fertiliser being applied to land.

Roles and functions under the RMA

The Ministry for the Environment

As the Government’s key advisor on the New Zealand environment, a function of the Ministry for the Environment is to provide advice on contaminated land issues. The function of the Minister for the Environment includes developing National Environmental Standards under the RMA. The Ministry is responsible for administering the RMA, and works in partnership with key sectors, organisations and communities to improve our environment.

Local government

Local government consists of regional councils and territorial authorities each with a specific contaminated land function under the RMA (see Box 1). Each council controls the activities in its area through policies and rules in district and/or regional plans. All land users must ensure their activities comply with the requirements of these plans and the RMA. Resource consents may be required for changes in land use, activities that have the potential to contaminate land, and activities on contaminated land. However, the requirements and the thresholds will vary between districts and between regions.

Box 1: Local government and its role under the RMA

Regional councils

There are 16 regional councils, including four unitary authorities (which have dual territorial and regional council functions). Regional councils:

- are generally organised along major catchment boundaries;
- prepare regional policy statements and regional plans;
- regulate discharges to air, water and land; and
- have the contaminated land function of: the investigation of land for the purposes of identifying and monitoring contaminated land.

Territorial authorities

There are 73 district and city councils, including four unitary authorities (which have dual territorial and regional council functions). District and city councils:

- prepare district plans;
- regulate land use, subdivision and building control;
- have the contaminated land function of: the prevention or mitigation of any adverse effects of the development, subdivision, or use of contaminated land; and
- also have a range of public health responsibilities under other legislation.

Because each council prepares its own plans, there is a lot of variability between plans in how they address contaminated land. A recent review of contaminated land provisions in district, regional and unitary plans highlighted the extent of this variability (Ministry for the Environment, 2006c). The review of district and city plans showed that:

- 33 percent of district and city plans featured no specific provisions relating to contaminated land;
- approximately 40 percent of plans have specific objectives, policies and rules relating to land use or remediation of contaminated land; and
- of the plans that have specific provisions, there is significant variability in how contaminated land is addressed.

Regional plans and policy statements are more consistent. Most regional plans address contaminated land, with 88 percent having specific provisions. However, there is still significant variation in terms of how each plan addresses contaminated land. Almost all regional policy statements prepared by regional councils under the RMA (15/16) contain objectives that as a minimum "highlight the need to manage the risks associated with contaminated sites on the environment (variously including protection of water ecosystems, land ecosystems, air resources, control of waste, community well being, human health and safety, etc)". Most regional policy statements (13/16) also, as a minimum, contain methods requiring the investigation of contaminated sites by the Regional Council (MfE, 2006)[5].

National Environmental Standards

The RMA enables the Minister for the Environment to prepare *National Environmental Standards* (hereon called standards). These standards have the force of regulations and are binding on local authorities. They can be established for a number of matters, including contaminants, or soil quality in relation to the discharge of contaminants.

There are currently no standards set out in regulation for contaminants in soil. However, the Ministry for the Environment has recently confirmed a work programme that includes:

> "Develop a standard and supporting guideline that provides:
>
> 1. a nationally consistent New Zealand based methodology for deriving soil contaminant levels for human health
>
> 2. numerical criteria for priority contaminants that define appropriate management actions i.e. the numerical criteria may:
>
>   (a) serve as conservative cleanup targets
>
>   (b) inform onsite management actions to reduce the potential for adverse effects
>
>   (c) trigger further investigation to determine site specific criteria."

To develop the standard a technical working group will be convened. This group will build on the work of a previous working group and is anticipated to have a similar membership. Membership will comprise of the relevant central government agencies (Ministry of Health, Ministry of Agriculture and Forestry, Environmental Risk Management Authority and New Zealand Food Safety Authority), and invite technical advice from local government and industry.

5 Contaminated Land – Review of District, Regional and Unitary Plans, unpublished report prepared for the Ministry for the Environment by Rosalind Day – Boulder Planning (Otago) Ltd, June 2006.

Guidelines and standards for contaminants in soil

Soil standards and guidelines provide a means for contaminant levels in soils to be monitored, evaluated and managed. Standards are defined in this report as legally enforceable numbers while guidelines are voluntary (see Box 2 for more discussion on the difference between standards and guidelines)

Box 2: The difference between standards and guidelines

There is often confusion over the purpose and status of standards and guidelines, what they mean, and how they are used. This confusion is increased by the interchangeable use of the terms ‘standards’ and ‘guidelines’. For the purpose of this report the following definitions are provided:

Standards are numerical limits, statements, or methodologies that are in a legally enforceable form such as a statute, regulations, and rules in a plan, or conditions in resource consents. For example, a rule in a plan may state that the concentration of a contaminant shall not exceed a specified level.

Guidelines are published by recognised authorities recommending the adoption of specified criteria to protect defined environmental uses and values. Guidelines may also explain the relationship between environmental quality and environmental uses and values. They may therefore explain the resource management options that are available to consent authorities. Guidelines have no legal status. However, they can be subsequently translated into standards by local authorities; for example, by reference in a regional plan rule.

While the above definitions are provided as a general guide, it is important to note that not all documents referred to as ‘standards’ are legally enforceable. Commonly referenced documents such as the Workplace Exposure Standards, Drinking Water Standards New Zealand and Standards produced by Standards New Zealand are not legally enforceable standards and in effect fall under the guideline definition (above).

Because of this interchangeable use of the terms ‘standards’ and ‘guidelines’ it is always advisable to check on a standard’s status rather than assume a standard is legally enforceable.

Guidelines

There is a range of New Zealand guidelines for contaminants in soil, as well as guideline values used internationally to monitor and manage contaminant levels in soils.

The Ministry for the Environment, in consultation with industry and local government, has developed a series of contaminated land management guidelines. These guidelines support the relevant local government functions under the RMA. The guidelines cover the following topics:

- Reporting on contaminated sites (Ministry for the Environment, 2003a)
- Hierarchy and application in New Zealand of environmental guideline values (Ministry for the Environment, 2003b)
- Risk screening system (Ministry for the Environment, 2004a)
- Classification and information management protocols (Ministry for the Environment, 2006b)
- Site investigation and management of soils (Ministry for the Environment, 2004b).

The Ministry also developed or supported a number of guidelines containing soil guideline values for specific contaminants of concern.

There are two New Zealand guidelines containing soil guidelines values for cadmium:

The "New Zealand Water and Wastes Association (NZWWA) guidelines for the safe application of biosolids to land in New Zealand" (NZWWA, 2003). These 'risk based' guidelines specify a 1 mg/kg soil limit for cadmium, above which the application of biosolids to land should cease. This soil limit is not specified for particular land uses, rather the soil limit is recommended for all soils where biosolids are used in New Zealand. The biosolids guidelines for cadmium were developed to protect against the uptake of cadmium into crops that are consumed by people, protect soil microbial health and to protect international trade against food standard exceedences.

"The Australian and New Zealand Guidelines for the Assessment and Management of Contaminated Sites" (ANZECC 1992). The guidelines include 'threshold based' cadmium ingestion levels for human health of 20 mg/kg and for environmental soil quality of 3 mg/kg. These guidelines have been largely superseded by the Ministry for the Environments contaminated land management guideline series.

The contaminated land management guideline series and the biosolids guidelines are widely used in New Zealand, at least by regional councils and unitary authorities [6], and are reported by users as being technically robust. While guidelines containing soil contaminant values like the biosolids guidelines have been written for a specific activity (biosolids application) the values are generally transferable to other activities that share similar hazardous substances. For example, the NZWWA biosolids guideline has been used by some regional councils to measure and assess cadmium present in soils as a result of phosphate fertiliser application, rather than the application of biosolids.

Although the level of use by territorial authorities has not been surveyed, it is likely to be much more variable.

Because the way the land is used influences the level of risk posed by a contaminant, guidelines generally specify guideline values for a range of land use scenarios (e.g. residential, agricultural, industrial/commercial). Higher levels of contaminants are usually accepted in soil which is used for high-density residential or industrial purposes, because the ground itself is likely to be covered by buildings or concrete, and thus people will have little or no contact with either the soil or food grown in the soil.

Agricultural standards or guidelines could be expected to be more stringent, as the soil is used for the purposes of growing food, which creates a potential 'pathway' by which people become exposed to cadmium (or other hazardous substances).

Guidance on the use of environmental guideline values

Typically, New Zealand practitioners rely on a mixture of national and international guidelines from which to select numerical values. However, the various New Zealand and international guidelines used contain different terminology and methodologies.

To reduce the confusion created by these differences, the Ministry for the Environment produced a guideline, in partnership with local government, called "Contaminated Land Management Guidelines No. 2: Hierarchy and Application in New Zealand of Environmental Guideline Values" (Ministry for the Environment, 2003b). CLMG No. 2 provides a best-

6The findings of a June 2006 survey of council officers at 14 of the 16 regional and unitary councils indicated that the guidelines were used by most respondents. The contaminated land management guideline series was used by 85–100 percent of respondents, while the main industry guidelines (timber treatment, oil industry, gasworks and biosolids) were used by most (70–83 percent) respondents (Ministry for the Environment, 2006d). The ANZECC 1992 guidelines were not surveyed.

practice hierarchy for selecting guidelines from the range of New Zealand and international guidelines available. CLMG No. 2 states a preference for New Zealand guideline values over international guidelines, and a preference for risk-based guideline values over threshold values. Based on these preferences, CLMG No. 2 sets out the following hierarchy for selecting guideline values:

1. New Zealand-derived, risk-based guideline values
2. Rest-of-the-world-derived risk-based guideline values, with a preference given to those that employ risk assessment methodologies and exposure parameters consistent with what is already used in New Zealand
3. New Zealand-derived threshold values
4. Rest-of-the-world-derived threshold values.

Box 3: The difference between 'risk-based' values and 'threshold' values

Environmental guideline values can be risk-based or threshold values.

Risk-based values are derived from a given exposure scenario (e.g. protection of human health), or the protection of a nominal proportion of species in an ecosystem.

Threshold values may be derived from toxicological data where insufficient data is available to calculate risk based values. Guideline values may also be classified as threshold values where insufficient information on their derivation is provided (e.g., lead guidelines, Ministry of Health, 1998). The level of protection afforded by threshold values is unable to be determined.

Issues associated with the use of guidelines for assessing cadmium in soil

Councils may choose different guideline values: The guideline value chosen by a council has the potential to have significant consequences for landowners and their land-use choices.

CLMG#2 outlines the best practice approach to selecting guideline for contaminants in soil. It is expected that this hierarchy should be followed. For example, Section 5.3 of Contaminated Land Management Guideline #5: Site Investigation and Analysis of Soils, entitled "Use and misuse of guidelines", notes:

> "Only guideline documents that are appropriate to the site conditions should be used, and you should have a thorough understanding of the basis of the derivation of the guideline numbers. Contaminated Land Management Guidelines No. 2: Hierarchy and Application in New Zealand of Environmental Guideline Values (Ministry for the Environment, 2003b) should be followed."

However, some local authorities may be unaware of this expectation, or may choose not to follow a recognised best practice approach. This can lead to adoption of inappropriate guideline values in some cases.

Some variations may occur between areas or regions when applying CLMG#2. For example, CLMG#2 leads to selection of the United Kingdom's figures of 1, 2 and 8 mg/kg for cadmium in residential soil of pH 6, 7 and 8. This can lead to a situation where different guidelines may apply to different properties due to either natural differences in soil pH, or use of lime on a particular site as a specific remediation measure.

Councils may apply guideline values differently: Councils may choose to apply trigger values (values which, if exceeded, 'trigger' a further investigation to assess the level of contamination) as threshold values (a number which, simply applied, everything coming under is ‘not contaminated’ and everything exceeding the threshold is ‘contaminated’).

This is mostly determined by the context of a particular investigation. In specific contaminated sites investigations, risk-based guidelines (ideally selected according to CLMG#2) are usually used to delineate the areas of contamination and act as *de facto* clean-up targets. Site-specific guidelines may also be developed, depending on the size and complexity of the site. By contrast, in regional council State of the Environment (SoE) surveying, guidelines are mostly used as trigger levels to denote the presence of an issue that may warrant closer investigation.

One significant difference between state of the environment surveying and contaminated site investigations is in the amount of attention paid to specific properties. State of the Environment surveying of soil involves sampling of one part of a property, with each location becoming merely one survey point in a larger network. Contaminated sites investigations are quite different, because these represent the detailed site-specific investigation of a single property. Exceeding a soil guideline in a single composite soil sample collected from a given property is not equivalent to identifying that property as a contaminated site. The detailed requirements of contaminated sites investigations are provided in the Ministry for the Environment’s Contaminated Land Management Guidelines series (most specifically CLMG#1, CLMG#2 and CLMG#5).

Guidelines do not specify a sampling depth or method: Cadmium tends to accumulate in the topsoil, because it is applied to the surface of the soil (via fertiliser) and binds reasonably strongly to the soil (Gray et al, 2003).

The Ministry for the Environment’s CLMG#5 provides guidance on soil sampling, including the range of sampling approaches that can be applied, the need to collected representative soil samples, and sampling depths applicable to surface soils (Section 3.6.2 of CLMG#5). The context of this guidance is contaminated site investigation.

Sampling depth is an important consideration when interpreting the applicability of guidelines. Guidelines are not provided with sampling depths attached, because these may vary depending on context. At contaminated sites it is relatively common to encounter pockets of contamination at a range of different depths, depending on the site history. Among experienced practitioners it is well understood that for any risk-based guideline, the sampling depth should aim to represent the key exposure pathways that were considered in the development of the guideline, and given the specific characteristics of the site. However, a lack of familiarity with this area may lead to some inconsistency between approaches taken by different councils

Voluntary industry limits on cadmium content of fertiliser

For some time (since 1995), the New Zealand fertiliser industry has had in place voluntary standards for the levels of cadmium in phosphate fertilisers. These voluntary standards were negotiated by the New Zealand Fertiliser Manufacturers’ Research Association (NZFMRA) and fertiliser companies. The new lower limits agreed to by industry were:

- July 1995 to Dec 1996 - 340 mg cadmium/kg P
- Jan 1997 onwards - 280 mg cadmium/kg P

As part of this voluntary reduction policy, the cadmium content of phosphate fertilisers was incorporated into the Fertiliser Quality Councils’ Fertmark quality assurance programme administered by Federated Farmers and subject to independent audit. The independent audit for the period January 2001 - June 2005 showed that the weighted average of cadmium content of phosphate fertilisers was between 149 mg cadmium/kg P and 193 mg cadmium/kg P. During this period no samples exceed the industry voluntary maximum of 280 mg cadmium/kg P.

Fertiliser manufacturers took the decision that no sample should exceed the 280 mg cadmium/kg P level - regardless of sampling or analytical error. This means that manufacturers need to produce single superphosphate with a cadmium content well below the 280 mg cadmium/kg P level.

In addition fertiliser recommendations for cropping situations where high phosphate inputs (e.g. potato, onion) have advocated for the use of high analysis NPK fertilisers. These fertilisers generally have a lower cadmium content than straight single superphosphate.

However, it should also be recognised that neither the voluntary industry limit, nor the weighted average cadmium contents achieved are yet sufficiently low to prevent cadmium from accumulating in New Zealand's agricultural soils as a result of phosphate fertiliser use. The overall average for cadmium in phosphate fertilisers over the last five year period (2001-2005) has been 175 mg cadmium/kg P.

Chapter summary

In New Zealand, there are systems currently in place to manage the different risks arising from cadmium in soils, food and phosphate fertiliser.

There are currently no official national-level standards for the permissible amount of cadmium in agricultural or residential soils or for the discharge of cadmium onto soil in New Zealand. There are a variety of different guidelines (some developed in New Zealand and others overseas) which councils may use to guide them in this assessment. These guidelines are not legally binding, unless councils give them legal effect by incorporating them into a regional or district plan, (although in court, a robust and credible guideline would have some weight as a widely held definition of 'best practice') or as a condition on resource consents.

The Ministry for the Environment has published a 'guideline to the guidelines' called the Contaminated Land Management Guidelines 2 (CLMG#2), which sets out a process for councils to follow select an appropriate guideline value for use in a contaminated site assessment.

The end-result of this regulatory environment is that, following the process set out in the CLMG#2, values currently used by some councils to indicate the requirement for a contaminated site assessment or to determine whether a site should be identified as contaminated on a LIM (Land Information Memoranda) or PIM (Project Information Memoranda) report issued under the Local Government Information and Meetings Act 1987 for cadmium range from 1 mg/kg to 22 mg/kg depending on land use. The guideline value chosen by a local authority has the potential to have significant consequences for landowners and their land-use choices. Guidelines should make reference to soil sampling depth and sampling method, in order to ensure consistency. Analytical methods should also be stipulated, to ensure comparable results.

At the industry level, there has been a voluntary initiative by the fertiliser industry to limit the amount of cadmium present in phosphate fertilisers, which is discussed further in Chapter 3.

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Chapter 3: Summary of current information on soil cadmium levels, inputs, and uptake by plants and animals

Introduction

In order to understand the level of risk, if any, posed by cadmium accumulation, it is necessary to trace the 'pathway' by which the risk could eventuate. In other words, we need to look at factors such as the current levels of cadmium in agricultural soils, whether these levels are increasing and at what rate, and what factors influence the uptake of cadmium from soil by plants and animals and thereby, the food system. The first part of this chapter discusses cadmium in the agricultural system, inputs from fertiliser, and reviews the factors which influence cadmium's cycling through the environment and the food chain, in order to provide an understanding of the many elements which govern the level of risk posed by soil cadmium accumulation.

The second part of this chapter aims to collate the best-available existing information on 'background' (natural) cadmium levels in New Zealand soils, current cadmium loadings in agricultural soils, and to make some rough projections as to expected increases in cadmium levels in the future. This section reviews current available data on cadmium levels in unmodified soils in current agricultural soils and potential future cadmium levels in order to give a 'picture' of New Zealand's soil cadmium status.

Cadmium in the agricultural system: from pasture to plate

Inputs of cadmium from fertiliser

Historical use of fertiliser

In their natural state, New Zealand soils have a range of fertility but deficiencies in major nutrients and trace elements are common, in particular the two main elements phosphorus (P) and nitrogen (N) (Cornforth, 1998). The development of commercial farming in the 1800s led quickly to a realisation that inputs of fertiliser would be needed to supplement these soil nutrient deficiencies. Single superphosphate was found to be most suitable and amounts of about 150 -250 kg per hectare were initially applied.

Use of phosphate fertiliser increased steadily as the dramatic increases in production due to its addition to the soil were obtained. Between 1961/62, when reliable records were first kept, and 1979/80, the use of phosphate fertiliser almost doubled from one to two million tonnes per annum (or, expressed as the elemental phosphorus content: 96,200 tonnes P to 180,100 tonnes P (Table 3.1).

The economic changes in the 1980s, particularly the removal of subsidies on fertiliser, had a dramatic impact on fertiliser use. Phosphate fertiliser use decreased from an estimated 1,996,000 tonnes in 1979/80 to a low of 836,500 tonnes in 1988/89 - the lowest level in more than a quarter of a century. Following this downturn there has been a steady increase in the amount of phosphate fertiliser used, to a high of 2,230,000 tonnes of phosphate fertilisers in 2002/03 (or 220,900 tonnes expressed as the elemental phosphorus content).

Current phosphate fertiliser use

By mass, superphosphate use is still dominant, accounting for about 87% of phosphate fertilisers applied.

Within pastoral agriculture, dairy farms use the most phosphate fertiliser, mostly in the form of single superphosphate. Application rates are typically 200-600 kg/ha/yr. Intensive dairy units usually apply superphosphate around the upper end of this range, whereas the more extensive farming operations (sheep, beef and deer) tend to apply the smaller amounts (Mills *et al*, 2004). In the 1992 AgResearch survey 22% of pastoral farms were applying more than 600 kg/ha/yr.

Within horticulture, requirements vary from crop to crop, but potatoes require the highest loadings of phosphate - typically 800 -1000 kg/ha/. Mills *et al* (2004) report from discussions with growers that, although not general practice, asparagus and apples can also receive single superphosphate at application rates of 200 - 400 kg/ha/yr and 100 - 200 kg/ha/yr, respectively.

Cadmium levels in phosphate fertiliser

All phosphate rock deposits contain cadmium. The amounts of cadmium present vary significantly, not only according to the type of phosphate rock deposit, but also within a single deposit. The cadmium content of the final product reflects the cadmium level in the unprocessed phosphate rock.

Sources of phosphate rock have changed over the years. No accurate historic records of imported rock phosphate have been kept but a general overview of rock origin and cadmium content is summarised in Table 3.6.

Historically, New Zealand sourced its phosphate rock from the Pacific Islands, particularly Nauru. It later emerged that Nauru rock contained some of the highest cadmium levels in the world - averaging about 450 mg cadmium/kg P. Manufacturing companies often used blends of different rocks - meaning that the cadmium content of the single superphosphate was usually less than that of Nauru rock.

Table 3.1: Estimated rock blends for manufactured superphosphate 1952-2005

Year	Phosphate rock source / blend	Cadmium (mg cadmium / kg P)
1952-1968	Dominantly Pacific Island rocks	200-490
1968-1975	Mostly Nauru/ some Christmas Island	200-450
1975-1983	50:50 Nauru/Christmas Island	200-50
1983-1996	Nauru/Christmas Island/North Carolina	200-450
1996-2005	China/Morocco/Togo	10-340

In 1995 the single superphosphate manufacturers embarked on a cadmium reduction programme which resulted in the phasing out of the Nauru supply. Rock was sourced from China, Morocco and Togo. Currently Morocco is the dominant source of phosphate rock used for single superphosphate manufacture in New Zealand.

Decisions by countries with low cadmium rock to classify phosphate rock as a ‘strategic material’ has resulted in these sources of supply becoming unavailable to New Zealand. In addition, in 2004, the Government of China imposed limits on exports of phosphate rock, and so it is currently unavailable to New Zealand (USGS, 2004).

Recent total national loadings from cadmium in fertiliser

Information about the use of phosphate fertiliser (about 2 million tonnes per year for each of the last five years) can be combined with the weighted average cadmium content (175 mg cadmium/kg P over the last five years) to estimate the overall mass of cadmium currently added to New Zealand agricultural soils.

Over the five year period from 2001 to 2005, approximately 150 tonnes of cadmium was added to New Zealand agricultural soils. Averaged over New Zealand's productive grasslands and horticultural areas (approximately 12.61 million ha), this would equate to approximately 2380 mg of cadmium added to each hectare for each of the last five years.

An estimated average national concentration increase in surface (0-7.5 cm) soils over the last five year period, assuming no losses, would be 24 µg/kg (0.024 mg/kg), approximately 5 µg/kg/year which is very close to the figure of 6.6 µg/kg/year identified from research data in Table 3.6. It should be noted that this is an average estimate and assumes no leaching i.e. inputs but no outputs. For example, soils of dairy farms would be expected to have accumulated cadmium at a higher rate than those of sheep and beef farms due to higher annual loadings of phosphate fertilisers.

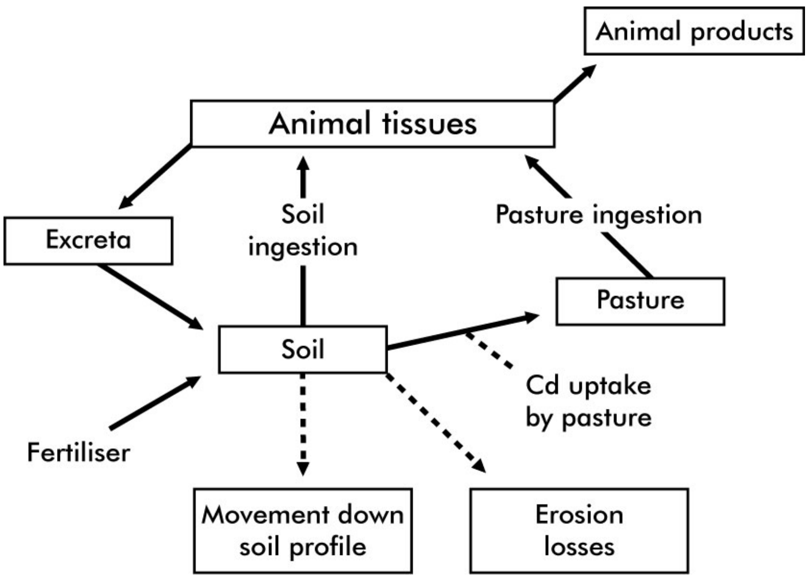
Cycling of cadmium in the agricultural system: an overview

There is considerable complexity involved in the movement of cadmium through a New Zealand pastoral system. There are several transfers, or 'pathways' of interest when examining the movement of cadmium from fertiliser through the agricultural and food systems. These are the transfers of cadmium from fertiliser to soil, from fertiliser to animals, from soil to animals, from soil to plants, and from plants to animals. In a general sense, average transfers from plants and animals to humans are examined in the New Zealand Total Diet Surveys (NZTDSs) (although it is also worth noting that these surveys do not distinguish between foods produced in New Zealand and imported foods).

These transfers are influenced by a number of factors. Some of these transfer pathways are now reasonably well characterised, and others are less well understood, leaving scope for debate.

Figure 3.1 gives a representation of the key movements of cadmium through the pastoral system (note: this will differ to the uptake of cadmium by plants in a horticultural system).

Figure 3.1: Transfers of cadmium in grazing system (adapted from Loganathan et al, 1999)



Soil-related factors which influence cadmium availability to plants

The range of factors which influence the bioavailability of cadmium in soils means that the total level of cadmium in soil does not necessarily correlate well with the plant-available fraction (that is, not all cadmium in the soil will be in a form that is available to plants) (BRS, 1997, p 17). Because of this complexity, uncertainty remains regarding the relationship between the levels of cadmium in soil, and the expected levels of cadmium in food grown on the same soil.

There are a number of soil-related conditions and factors which influence the uptake of cadmium by plants. Changes in these factors may make cadmium more mobile and available, or conversely, may fix the cadmium and render it unavailable for uptake by plants or other organisms.

The main factors which *increase* the uptake of cadmium by plants are the amount of cadmium present, greater acidity (a lower soil pH), and a low organic matter content, and increased salinity. After the total metal concentration, the major factor affecting the bioavailability of positively charged metals in soils is generally found to be acid (low pH). In acidic soils, proportionately more cadmium is released to the soil pore-water, therefore making it more available to plants. In strongly alkaline soils, cadmium is more strongly fixed by the solid phases and becomes relatively unavailable to plants (BRS, 1997). More saline soils also promote greater uptake of cadmium by plants through formation of soluble cadmium chloride complexes. This is an issue in Australia, but fortunately, saline soils are not widespread and relevant to New Zealand.

Levels of cadmium in the soil and further addition of cadmium

It is known that the plant available fraction increases in magnitude as the total concentration of cadmium in the soil increases (Taylor, 1997). Several other New Zealand researchers have also reported a relationship between the total or available cadmium content of the soil and uptake in plants and animals (Longhurst *et al*, 2004; Roberts et al, 1994; Loganathan and Longhurst, 2002; Roberts and Longhurst, 2002; Loganathan et al. 1999; Taylor and Theng, 1994; Gray *et a*l, 2001)

The relationship between phosphate fertiliser and soil cadmium levels is relatively well established. The consensus is that cadmium is not particularly mobile, and application of phosphate fertiliser containing more than about 50 mg cadmium/kg P leads to an accumulation of cadmium in topsoils (Bramley,1990; European Commission CSTEE, 2002). Different forms of cadmium do not have the same bioavailability to plants. Cadmium impurities in phosphate fertilisers are more plant-available than natural background cadmium derived from geological sources (BRS, 1997).

Reported total cadmium concentrations in surface soils of several of New Zealand’s trading partners (in mg/kg) are: USA 0.05 - 1.5 ppm (mean for clay soils 0.27 mg/kg): Canada 0.10 - 1.8 ppm (mean for various soils 0.56 mg/kg); Denmark 0.8 - 2.2 ppm (mean for various soils 0.26 mg/kg), Japan 0.03 - 2.53 mg/kg (mean for various soils 0.44 mg/kg) and Great Britain 0.27 - 4.0 ppm (mean for various soils 1.0 mg/kg) (Kabata-Pendias & Pendias, 2001, Roberts *et al* 1992).

Comparable data for Australia has been harder to locate, partly due to a tendency for Australian researchers involved in the larger surveys to focus on the EDTA-extractable fraction of cadmium, which is only a part of the total concentration. Merry and Tiller (1991) reported a cadmium range of 0.01-0.73 mg/kg (mean 0.18 mg/kg) as the EDTA extractable fraction for 516 pasture soils east of Adelaide. McLauglan et al (1997) reported a range of 0.03 - 0.61 mg/kg as the EDTA extractable fraction, over 352 sites spread over Australia’s potato-growing regions. However, Jinadasa et al (1997) reported total topsoil cadmium concentrations of 29 farms and background soils in the Greater Sydney Region to range from 0.11 to 6.37 mg/kg. More recently, Mann et al (2002) reported total concentrations of cadmium in 23 Western Australian soils to range from 0.07 mg/kg (an unfertilised soil) to 3.2 mg/kg (a fertilised soil).

Overall, it is evident that New Zealand soil cadmium values are within the ranges reported by these trading partners, with the possible exception of the USA and Denmark which report lower mean levels.

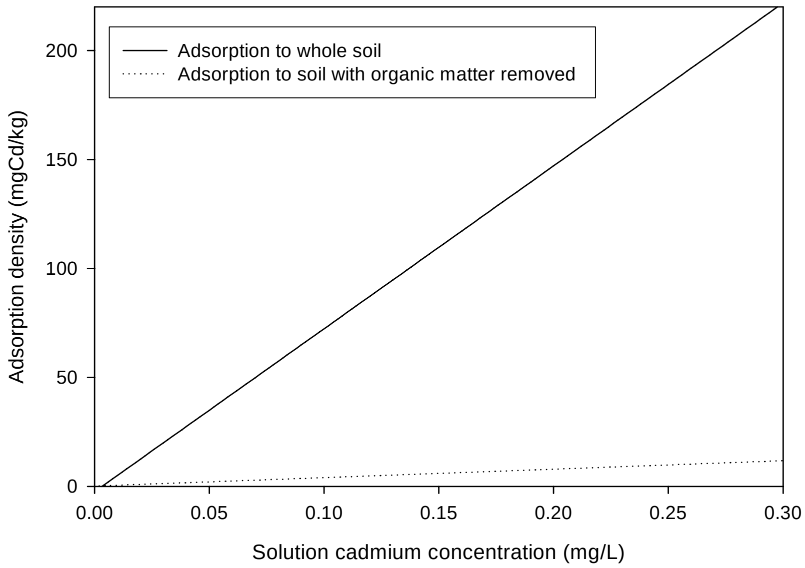
Soil characteristics

The uptake of cadmium by plants depends on the amount of cadmium that can be released from the solid phases of the soil (to which cadmium is bound) into the soil pore-water (also called the soil solution) surrounding the solid grains and plant roots. This is a process that is always in equilibrium, with most cadmium at any time being present in the soil's solid phases, and a small amount being present in the soil pore-water.

Release of cadmium to pore-water (and uptake by plants) can be inhibited by the metal sorption (fixation) to the soil. Metal sorption is influenced by the presence of highly adsorptive solid phases present in the soil: particularly: organic matter, clay minerals, and iron and manganese oxides. One broad measure of a soil's ability to retain trace elements is its cation exchange capacity (CEC). To a first approximation, a soil's CEC represents its ability to retain positively charged metals such as cadmium (Cd^{2+}) by electrostatic attraction alone. Such trace elements displace (exchange with) major elements (Ca^{2+} and Na^{+}) associated with negatively-charged surfaces present in the soil. Beyond this, cadmium and other trace metals can form stronger (covalent) bonds with specific functional groups present in or on soil organic matter, clay minerals and iron and manganese oxides which may reduce bioavailability and uptake by plants.

For cadmium which forms very strong bonds with the element sulphur, the strongest bonds are likely to be to reduced sulphur (thiol) groups that are present in soil organic matter. Soil organic matter is therefore one of the more important soil factors governing the bioavailability of cadmium in soil. Organic matter fixes cadmium in the soil, making it less mobile and phytoavailable. Conversely, when organic matter is removed from soil, cadmium becomes more available for plant uptake (Kim & Fergusson, 1992) (Figure 3.2)

Figure 3.2: Reduction in adsorption of cadmium to a New Zealand soil (Tai Tapu Silt Loam) when the soil organic matter is removed (Kim & Fergusson, 1992)



This has implications for horticultural systems, and the intensive arable sector which typically experience declining levels of soil organic matter.

Conversely, increasing the levels of organic matter or other adsorptive phases (particularly iron and manganese oxides) will tend to lower the release of cadmium to the soil solution and thereby impede cadmium uptake to plants.

Soil iron and manganese oxides are also highly adsorptive phases for trace elements in soils, due to a combination of their high surface areas and pH-dependent surface charge characteristics. Kabata-Pendias and Pendias (2001) note that cadmium adsorption to organic matter and iron and manganese oxides has been widely studied, and these studies lead to the generalisation that in acid soils, organic matter and iron and manganese oxides largely control cadmium solubility (release to porewater).

The same authors also note that “in nearly all publications on the subject, soil pH is listed as the major soil factor controlling both total and relative uptake of cadmium” (Kabata-Pendias and Pendias (2001). The dominance of pH as a controlling variable should not be seen as separate from the topic of adsorptive phases, but a master variable that works by influencing the same equilibrium processes. More acidity is the same thing as more free protons (H^{+}_{aq} ions). Protons directly compete with cadmium for surface adsorption sites (on clay minerals, organic matter and iron and manganese oxides), and also change the surface charge characteristics of these soil phases. The effect of pH on cadmium fixation and release can therefore be conceptually approximated as simple competition between protons and cadmium for the same surface fixation sites in the soil. At higher pH values (less protons), more cadmium is fixed, and as the pH decreases (more protons), more cadmium is released.

Two other factors that increase uptake of cadmium by plants are zinc deficiency in soils and greater aeration. Anaerobic conditions, such as flooding, reduce the uptake of cadmium by plants (Chaney and Hornick, 1978). The net effect of such factors are more complex, but in general they operate by influencing the same equilibrium processes. Zinc (Zn^{2+}) competes with cadmium for both adsorption sites in the soil and uptake through plant root cell membranes. The impact of zinc may therefore be to increase cadmium in porewater, but decrease uptake into plants (Alloway, 2008). Aeration results in the faster oxidation (breakdown) of soil organic matter, potentially causing its adsorbed cadmium load to be released (Figure 3.2). This is partly through increased microbial activity. As a secondary effect, increased microbial respiration associated with aeration may result in higher partial-pressures of carbon dioxide in porewater, which would reduce the pH (Weihermuller et al 2007). Aeration may therefore act via two cadmium controls: soil organic matter and pH. Conversely, anaerobic conditions inhibit the oxidation of soil organic matter.[7]

Working with soil properties to reduce bioavailability of cadmium

Some management techniques can reduce the amount of bioavailable cadmium by fixing it through natural process, for example, liming soil to reduce its acidity, or increasing the levels of organic matter. Unless limed, pastoral systems will generally become more acidic over time due to superphosphate, urea and urine inputs. The availability of cadmium in the soil and uptake by plants and animals can therefore be expected to increase, unless remedial action is taken (Bramley, 1990). One problem with relying on fixation methods is that, although they render the cadmium less mobile and therefore reduce plant uptake, changes in soil conditions can result in remobilisation occurring. An international concern is that due to the gradual increase of cadmium in soils and decrease in soil pH, overall transfer of cadmium to the food chain will grow significantly with time (Kabata-Pendias and Pendias, 2001).

In the context of the New Zealand farming system, there is limited scope to work with some of these soil properties to reduce cadmium uptake as demonstrated in Table 3.2. Most New Zealand soils are naturally acidic or highly acidic, and remain acidic with liming. In addition, the optimum soil pH range for pasture grass is acidic (5.8 to 6.3) and this would need to be closely monitored and maintained by the farming community.

Table 3.2: Recommended practices to reduce Cadmium uptake into food crops

- Use phosphate fertilisers with low levels of cadmium
- Maintain soil pH at the upper recommended limits for crop type
- Maintain high organic matter in soil
- Alleviate any zinc deficiency in the soil
- Avoid acidifying fertilisers, including calcium ammonium nitrate (CAN)
- Phosphate fertiliser applications should be banded (and not broadcast) where possible
- Avoid fertiliser blends and irrigation water containing high levels of chloride
- Use crop varieties which demonstrate a lower level of cadmium uptake

(adapted from: Chaney and Hornick, 1978; McLaughlin *et al*. 1996)

Plants and their uptake of cadmium

The cadmium content of plants is significantly correlated to the levels of cadmium in the soil in which they are grown, and soil pH (Kabata-Pendias and Pendias, 2001). There are also several key crop-related factors which influence the uptake of cadmium by plants. There are, in order of importance:

- the crop species and cultivar;
- different types of plant tissue;
- leaf age, and

7 However, in cases where cadmium is mainly bound to soil iron and manganese oxides (e.g. when organic matter content is low), anaerobic conditions may work to cause its release, by causing the metal oxides to be chemically reduced (Fe3+ becomes dissolved Fe2+)

- metal interactions (Chaney and Hornick, 1978).

The most important crop-related factor is the species and cultivar type. In general, when grown in the same soil, cadmium accumulation by different plant species has been shown to decrease in the order leafy vegetables > root vegetables > grain crops (Grey *et al*, 1999). Within a single plant, cadmium concentrations differ between parts. The older the age of the leaf, the more cadmium it will contain. Lastly, increasing soil concentrations of zinc can reduce the uptake of cadmium (Chaney and Hornick, 1978). This is presumably by competition between cadmium (Cd2+) and zinc (Zn2+) during their uptake across the root membrane. However, although zinc *tends* to result in decreased cadmium uptake, this type of interaction is complex (Alloway, 2008), and such an effect is not always evident under actual field conditions (Nan *et al*, 2002).

While levels of soil contamination by cadmium in Australia and New Zealand are generally commensurate with those reported by a number of our trading partners, Australia and New Zealand have plant production systems that rely more heavily on plant–microbe symbioses (e.g. *Rhizobium*, mycorrhizae) which are very sensitive to metal inputs (Chaudri *et al.* 1993; Alloway, 2008). Soils in Australia and New Zealand may also be more sensitive to metal contamination than those in the northern hemisphere (McLaughlin *et al.* 1997*a*, 1997*b.)*

Cadmium uptake by animals

Grazing animals can take up cadmium by eating crops, pasture, soil[8], or phosphate fertiliser directly. Good farm management practices should minimise ingestion of soil and phosphate fertiliser but, in practice, some uptake from these sources is unavoidable.

The amount of cadmium taken up by grazing animals will depend on the level of cadmium they are exposed to through pasture, soil, or fertiliser, throughout their lifetime. Obviously, the higher the level of cadmium in these sources, the higher the exposure to grazing animals will be all other factors being equal.

As is the case with humans, only a fraction of the cadmium ingested by grazing animals is absorbed through the gastro-intestinal tract and into the blood stream. Van Bruwaene *et al* (1984) (cited in Bramley, 1990) found that of the amount of cadmium ingested, 0.3%- 0.4% is retained by goats and 0.75% is retained by cattle. This research suggested that 80-90% of cadmium ingested by cattle will be excreted within 14 days. Doyle *et al* (1974) (cited in Bramley, 1990) found that growing lambs absorbed around 5% of cadmium given at dietary concentrations of 60 mg/kg.

As in humans, cadmium tends to accumulate in animals particularly in the tissues of the kidney and liver. Cadmium builds up over the life of the animal, and so the kidneys and livers will show higher cadmium concentrations depending on the age of the animal (all other factors being equal).

Current and future soil cadmium levels in New Zealand

Background to the national soil cadmium study

In 2006 the Ministry of Agriculture & Forestry (MAF) engaged Landcare Research Ltd to establish a system providing national coverage of a cadmium baseline, current and future levels. This new dataset includes the AgResearch 1992 data and all available data obtained

8 The amount of soil ingested in a year by a grazing ewe has been estimated at around 23 kg, and for a cow, 250 kg (Bramley, 1990).

since that time. Cadmium data from over 1800 soil samples have been compiled allowing a more accurate assessment of the national situation than has been previously possible, although difficulties with interpretation exist due to inconsistent sampling depth. Also, there remain notable gaps in the coverage of some regions (e.g. West Coast, Gisborne). Nine regions have less than 100 samples.

Methods

Data sources of cadmium data were identified by Landcare Research with the help of MAF. Samples were topsoils of varying depth to a maximum of 40 cm. Most samples were 0 to 10 or 0 to 7.5 cm depth. The average sample depths for background, pastoral, cropping and horticultural soil samples were 10.0, 9.4, 14 and 13 cm respectively. Cropping and horticultural soils are regularly mixed due to cultivation, while pastoral and background soils often are not cultivated. There was not a standardisation of sampling depth for the different land use types which may have an influence on interpretation of the data.

Data from a total of 1842 dried topsoil samples were collated. Samples were mainly collected at two time periods 1989-1995 and 2000 to the present, and the results presented here may underestimate the present situation. Sampling strategy and protocol varied with the purpose of sample collection. Some samples were for specific experiments while others were for regional or national surveys. Testing for cadmium was either by strong acid extraction (in general *aqua regia* or equivalent) of the soil followed by atomic spectroscopic or mass spectrometric analysis, or by X-ray fluorescence spectrometry of the whole soil. X-ray fluorescence is not a particularly appropriate method for assaying cadmium in soil due to its high detection limits; however, the majority of samples were analysed as acid extracts using more sensitive atomic spectroscopic and mass spectrometric methods. These have ranged from Graphite Furnace Atomic Absorption Spectroscopy (GFAAS) for the earlier samples (including the 1992 survey), through to Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES), and Inductively Coupled Plasma Mass Spectrometry (ICP-MS) in the more recent samples.

Some samples had associated grid references suitable for plotting on maps while others only had regional location data. Other samples included land use data but were not geo-referenced. Samples from sites of known cadmium contamination were not included in the database analysis. Where possible, the largest set of samples was used for analysis. Relationships between possible drivers of variation such as soil group, land use, vegetation, climate, regional fertiliser use, etc., were investigated.

A selection of 375 of these samples from sites with land-uses reserve, tussock, bush, indigenous forest, plantation forestry and “unfertilised” control sites were used to derive baseline levels of cadmium in New Zealand topsoils (Table 3.3). Because it had the largest number of samples, the landuse “unfertilised” has the largest influence on the result. It also has the highest cadmium concentrations of the background soils, possibly as a result of contamination, e.g., fertiliser drift or animal transfer. It was impossible to identify conclusively if these samples were contaminated or not and both a total background average (0.16 mg/kg) and a background without unfertilised average (0.11 mg/kg) are reported. These data are similar to that found for non-farmed soils (0.20 mg/kg, Roberts et al. 1994). Baseline cadmium was consistent across all regions and soil types.

Results of the study for national average cadmium levels

National average background

Based on an analysis of soil samples from various studies, New Zealand has a national average baseline (i.e. the ‘natural’ background level in soils) value for cadmium of 0.16 mg/kg, (n = 375, range 0.00 - 0.77 mg/kg, Table 3.3) consistent across all regions and soil types. The current national average soil concentration for cadmium (based on all samples) is 0.35 with a range of 0-2.52 mg/kg (n= 1714, Figure 3.3, Table 3.4).

National average cadmium concentrations and land-use

Land-use was a key driver of topsoil cadmium concentrations. Cropping, pasture and horticulture land-uses all had higher concentrations of cadmium in soil than background land-use (Figure 3.4, Table 3.3). Dairying has the highest national average soil cadmium concentration (0.73 mg/kg) and showed the largest number of data points outside the 90 and 10 percentiles for the pasture landuse, reflecting the wide range of cadmium values measured. Kiwifruit (0.71 mg/kg), berries (0.68 mg/kg), orchards (0.66 mg/kg), market gardening (0.46 mg/kg), beef farming (0.42 mg/kg) and unspecified drystock pasture (0.40 mg/kg) were also above the national average. Deer and horse enterprises were also associated with higher average concentrations of soil cadmium (0.68 mg/kg and 0.53 mg/kg respectively). However, there were few samples, and these farms were from one region - the Waikato, and may have previously been used for dairying. They may not reflect national trends. Cropped soils appear to be mostly below the national average of 0.35 mg/kg for cadmium; however, these soils are tilled to a greater depth (20 cm) than other land-uses, and dilution decreases the cadmium concentration. Soils where tobacco was grown were more elevated in cadmium (0.34 mg/kg) than other cropping soils. These soils will now have other land-uses as tobacco is no longer grown in New Zealand. Sheep farming was slightly below (0.33 mg/kg) the national average.

Table 3.3: Background soil cadmium (Cd) topsoil concentrations by land use (sampling depth 10cm)

Landuse	Number of samples	Average Cd (mg/kg)	Range (mg/kg)
Native	70	0.10	0.00-0.39
Forestry	42	0.14	0.02-0.65
Parks	36	0.11	0.06-0.20
Tussock	4	0.08	0.07-0.09
“Unfertilised”	223	0.19	0.02-0.77
Background (excluding “unfertilised”)	152	0.11	0.00-0.65
Total Background	375	0.16	0.00-0.77

Figure 3.3: National map of topsoil cadmium levels (NB. The unit µg g-1, or parts-per-million, is equivalent to the unit mg/kg used elsewhere in this report.)

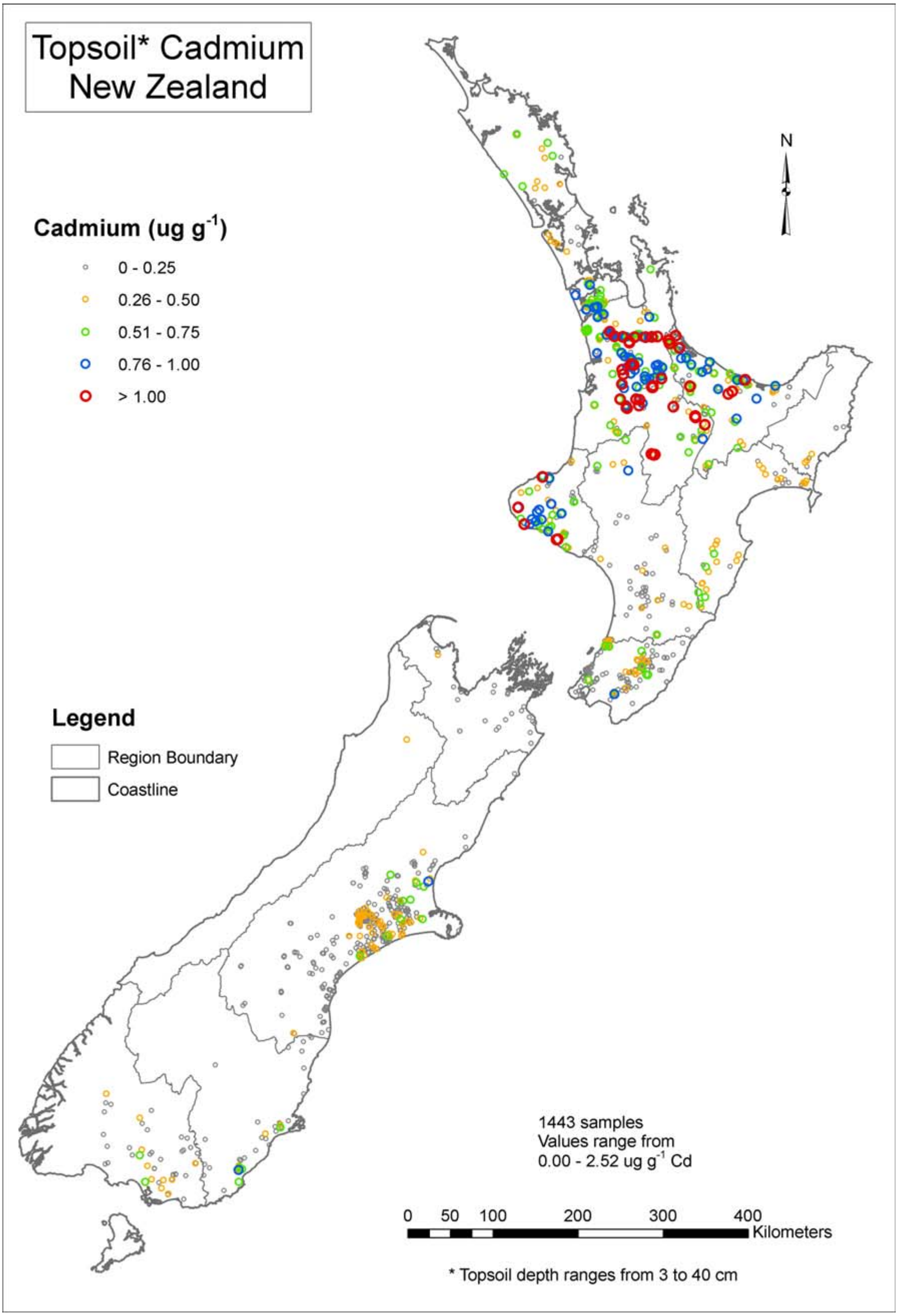
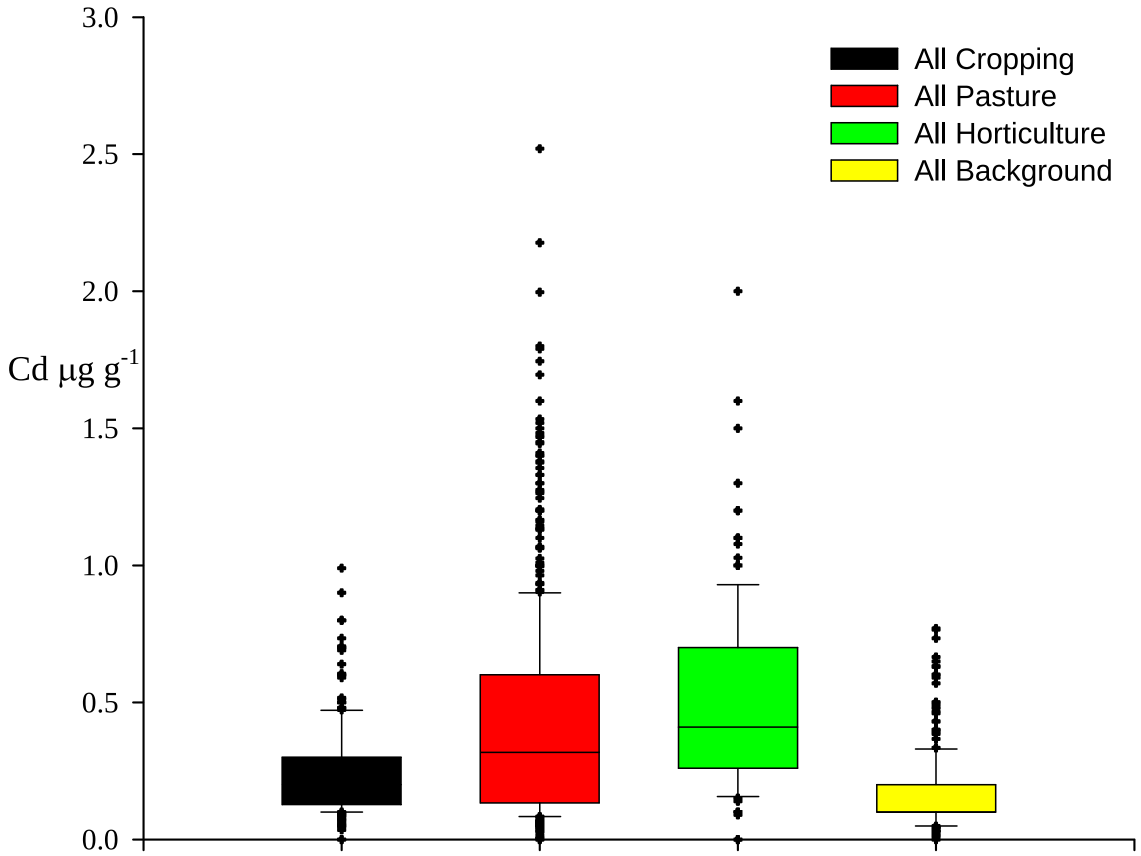


Table 3.4: Topsoil cadmium concentrations in landuse classes

Landuse	**Number of samples**	**Average Cd (mg/kg)**	**Range (mg/kg)**
All Landuses	1842	0.35	0.00–2.52
All Cropping Average sampling depth: 14.0 cm	301	0.24	0.00–0.99
Barley	6	0.15	0.10–0.25
Maize	11	0.25	0.10–0.40
Peas	3	0.15	0.11–0.17
Tobacco	5	0.34	0.20–0.70
Wheat	38	0.17	0.09–0.16
All Pasture Average sampling depth: 9.4 cm	840	0.43	0.00–2.52
All Drystock	111	0.40	0.00–1.40
Dairy	144	0.73	0.00–2.52
Deer	12	0.68	0.40–1.20
Beef	48	0.42	0.04–1.40
Horses	4	0.53	0.40–0.60
Sheep	34	0.33	0.03–1.20
All Horticulture Average sampling depth: 13.0 cm	296	0.50	0.00–2.00
Berries	50	0.68	0.20–1.20
Kiwifruit	37	0.71	0.30–1.20
Vineyard	12	0.38	0.20–0.70
Market Gardening	142	0.46	0.00–2.00
Orchard	49	0.66	0.10–1.50

Figure 3.4: Boxplots of cadmium in soil in 4 major landuse classes (Boxes are the 25th and 75th quartiles, while whiskers are the 10 and 90 percentiles. The unit µg g^{-1}, or parts-per-million, is equivalent to the unit mg/kg used elsewhere in this report). The average sample depths for background, pastoral, cropping and horticultural soil samples were 10.0, 9.4, 14.0 and 13.0 cm respectively



Results from modelling the future accumulation of cadmium in soils

Projections of the time that soil cadmium concentrations would take to reach specific soil levels were developed using the New Zealand Fertiliser Manufacturers Research Association Cadbal Model. The model is a mass balance model developed in 1996 and updated in 2005. Projections were carried out using the relevant standardised inputs that reflect current management practise for regional farming systems for sheep/ beef, dairy and potatoes. Based on measured data from the cadmium database, 287 scenarios were run. This model only produces results based on the New Zealand Soil Generic Classification (Taylor 1948, Taylor & Cox 1956, Taylor & Pohlen 1962).

Results showed Brown Grey Clay Loams, Yellow Brown Loams and Yellow Brown Podzols soils accumulated more cadmium than the other soil types while alluvial, Yellow Brown Earths and Yellow Grey Earths soils accumulated the least cadmium. Differences in soil type cadmium accumulation appear due to differences in leaching losses and soil bulk densities input to the model.

The model also showed pastoral farming resulted in increased soil cadmium content in all regions and nationally. The peat soils of the Waikato region showed the highest potential for cadmium accumulation. The regions with the highest present-day soil cadmium content also have the highest potential to accumulate cadmium in the future.

Sheep/beef farming led to more accumulation of cadmium than dairy when both are under the same fertiliser regime although, dairy farming requires more fertiliser for optimal production than beef and sheep farming in practice. The difference in accumulation was due to the difference in sedimentation losses (900 kg ha^{-1} y^{-1} for dairy farming and 500 kg ha^{-1} y^{-1} for sheep and beef). However, sedimentation losses are due to a range of factors including topography, soil type, leaching class and climate, not just farm type, and this result should be interpreted cautiously.

Cadmium levels in soils under dairy farms were shown to decrease in cadmium with time once soil cadmium exceeded about 1.3 mg kg^{-1} due to the model's simple linearity and assumptions about removal of sediment, erosion products and leaching. If the cadmium is not held on the soil it must go somewhere. This result, if able to be confirmed by empirical observation, would have important implications for farm sustainability and potential off site environmental and human health effects, and its accuracy should be further investigated. For example, the model does not take into account the fact that organic matter tends to accumulate in soils under pasture which can adsorb additional cadmium (Figure 3.2). Also, the NZ drinking water standard for cadmium is only 0.004 mg/kg (4 µg/L), and increased leaching of cadmium to groundwater would have potential implications in relation to the quality of rural borewater supplies. In reality, some dairy farms significantly exceed 1.3 mg/kg cadmium in soil, and there is no empirical evidence in support of a levelling off or decline at or above this concentration.

Increasing the sampling depth from 0–7.5 to 0–10 to 0–20 cm was shown to dilute the cadmium concentration effectively from 0.43 mg/kg to 0.37 mg/kg to 0.26 mg/kg for a Yellow Brown Earth under dairy (30 kg P $ha^{-1}y^{-1}$). The published research literature however shows various levels of declining cadmium concentration with sample depth. Recent Environment Waikato data shows that in the top 20 cm the decline may be more limited in Waikato soils.

Regional soil cadmium results

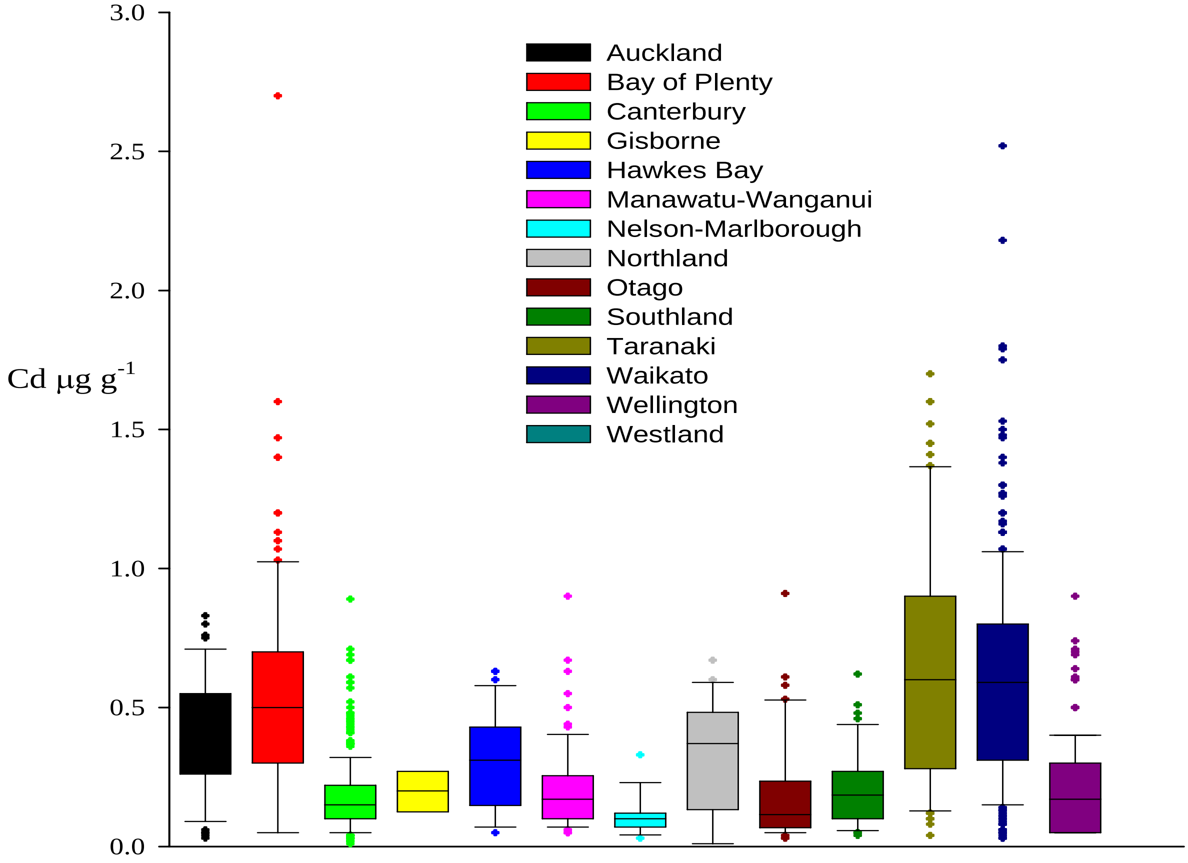
The region with the highest average cadmium concentration (over all land uses, including reserves) was Taranaki (0.66 mg/kg) (Table 3.5). Other regions with similar cadmium concentrations include Waikato (0.60 mg/kg) and Bay of Plenty (0.52 mg/kg). Dairy farming with high fertiliser use is traditional in these areas and likely to be the cause of the elevated levels. The regions with the lowest average cadmium concentrations were Canterbury (0.17 mg/kg), Gisborne (0.20 mg/kg), Manawatu-Wanganui (0.17 mg/kg), Nelson-Marlborough (0.23 mg/kg), Otago (0.20 mg/kg), Southland (0.21 mg/kg) and Wellington (0.20 mg/kg), all historic sheep farming areas.

Table 3.5: Number of topsoil samples, average and range of cadmium concentration per region

Region	**Number of samples**	**Average (mg/kg)**	**Range (mg/kg)**
Auckland	198	0.32	0.03-1.10
Bay of Plenty	131	0.52	0.05-1.60
Canterbury	453	0.17	0.01-0.89
Gisborne	8	0.20	0.05-0.27
Hawke's Bay	36	0.31	0.05-0.63
Manawatu-Wanganui	78	0.17	0.04-0.9
Nelson-Marlborough	50	0.23	0.03-1.00
Northland	27	0.33	0-0.67
Otago	43	0.20	0.03-0.91
Southland	51	0.21	0.04-0.62
Taranaki	84	0.66	0.04-1.7
Waikato	380	0.60	0.03-2.52
Wellington	174	0.20	0.05-0.90
Westland	1	0.40	-
National	1714	0.35	0-2.52

The regions of Canterbury and Waikato had the highest number of samples (453 and 380 respectively). The regions of Bay of Plenty (131), Taranaki (84) and Wellington (174) are also relatively well represented. Regions with low numbers of samples, where further sampling would be beneficial to increase confidence, include Gisborne (8), Hawke's Bay (36), Northland (27) and Westland (1).

Figure 3.5: Boxplots of cadmium in soil according to region showing mean, quartile and 90% confidence levels (NB. The unit µg g-1, or parts-per-million, is equivalent to the unit mg/kg used elsewhere in this report.)



Previous estimates of Cadmium accumulation rate in New Zealand agricultural soils

A key feature evident from the distribution of results illustrated for all regions (Figure 3.5) is that some farms have accumulated more significantly cadmium than others. Waikato and Taranaki have the highest range of cadmium levels followed by Bay of Plenty. The range for all other regions does not exceed 1 mg/kg.

The pattern of historic average and maximum accumulation is illustrated for six previous studies in Table 3.6.

Table 3.6: Estimates of net cadmium accumulation rates (µg/kg/year) in topsoils over various survey regions between 1939 and the time of each survey.

Survey scope	**Apparent net cadmium accumulation rate in soil (µg/kg/year)**		**Soil sampling depth**	**Date of survey**
	Mean	Maximum		
NZ wide: pastoral soils[a]	4.5	25.1	0-7.5 cm	1992
NZ wide: pastoral and horticultural soils[b]	11.8	30.0	0-15 cm (mostly)c	1990
Waikato: horticultural soils[d]	8.1	21.1	0-7.5 cm	2003
Waikato: pastoral soils[d]	9.0	18.3	0-10 cm	2002
Auckland: horticultural soils[e]	4.8	14.3	0-7.5 cm	2002
Tasman: horticultural soils[f]	1.6	12.5	0-7.5 cm	2003
Overall averages	6.6	20.2		1999

a Derived from data in Longhurst et al (2004).

b Derived from data in Taylor (1997).

c From reference [b]: ‘Archived soil samples were either single pit samples or composite core samples usually 0-6 inches (0-15 cm) in depth. Present day samples were a composite of 20 cores taken at the same depth as the corresponding archived soil.’

d Kim (2005).

e Derived from Gaw 2002.

f Derived from Gaw 2003.

In relation to the highest and lowest mean apparent net accumulation rates (Table 3.6), the low value for horticultural soils of Tasman District is likely to be related to the fact that these soils are sandy, and will have a lower cadmium retention capacity than most other New Zealand soils. At the other end of the scale, the high mean value of 11.8 µg/kg/year (~0.012 mg/kg/yr) is based on archived soils, and probably contains some bias towards properties on ‘easy and accessible’ land that were settled early, and long-established dairy farms (Taylor, 2008). These low and high results tend to balance each other, and the mean historic average accumulation rate of 6.6 µg/kg/year remains the same whether they are included or excluded from the data set.

Earlier in this chapter, it was estimated that the average loading rate (excluding losses) for cadmium on New Zealand pastures over the recent five year period 2001-2005 was approximately 4.8 µg/kg/year. Assuming that an average of 90% of this (4.3 µg/kg/yr) is retained in topsoils (Loganathan et al, 1997), we could estimate that the current average rate of cadmium accumulation in New Zealand agricultural soils may be approximately 65% of the average historic accumulation rate (6.6 µg/kg/yr).

This estimate is consistent with the voluntary industry reduction in cadmium in phosphate fertilisers to a maximum of 280 mg/kg P which occurred from 1997 (and a lower average than this over recent years that would have been countered to some extent by an increased use of superphosphate fertiliser). The voluntary limit of 280 mg/kg P was said to represent a reduction in the cadmium content of phosphate fertilisers by one-third.

Upper accumulation rates are generally more consistent with each other in the first instance, and average about 20 µg/kg/year (0.02 mg/kg/yr) (Table 3.6). It can be seen that the upper accumulation rate is about three times the average accumulation rate.

Chapter summary

Cadmium in the agricultural system: from pasture to plate

Over the period from 1990 when superphosphate first reached over 1 million tonnes applied, there has been a steady increase in the amount of phosphate fertiliser used in New Zealand to a high of over two million tonnes in 2002/03 (or 220,900 tonnes expressed as the elemental phosphorus content). Superphosphate application levels have declined to 1,259,000 tonnes in 2006. Over the last five year period (2001-2005), approximately 30 tonnes per annum of cadmium were added to New Zealand’s agricultural soils through phosphate fertiliser use.

Historically, New Zealand has sourced its phosphate rock from Nauru, which was very high in cadmium relative to other phosphate rock sources, averaging about 450 mg cadmium/kg P. In 1995, the superphosphate manufacturers embarked on a cadmium reduction programme which resulted in the phasing out of the Nauru supply. A voluntary industry limit for cadmium content in phosphate fertiliser of 280 mg Cd/ kg P was imposed. The limit has been consistently bettered over recent years. From 2001 to 2005 the weighted average content of cadmium in phosphate fertiliser was about 180 mg Cd/kg P.

There is currently no cost-effective or practical method of removing cadmium from phosphate rock. Low-cadmium containing phosphate rock is either unavailable or difficult and more expensive to source.

The cycling of cadmium through agricultural systems is complex, and influenced by many factors. The amount of cadmium present and soil conditions including acidity (pH), organic matter, and salinity, can increase the amount of cadmium taken up by plants. The availability of cadmium is increased by soil acidity and decreased by the presence of organic matter or other significant adsorptive phases (such as iron and manganese oxides) in soils.

Plant-related factors that influence the uptake of cadmium include: the crop species and cultivar; the types of plant tissue; leaf age and metal interactions. Generally, cadmium is stored mostly in leaves, then in roots, seeds and fruit.

Animals can take up cadmium from eating fertiliser directly, through soil uptake during grazing or as a result of eating pasture plants containing cadmium. Of these, the intake of cadmium via pasture is the most significant on average. Cadmium accumulates in the kidneys and livers of grazing animals over time, and so increases in these organs as animal’s age.

Results of national study of cadmium levels in New Zealand

Based on the analysis of soil samples from various studies, New Zealand has a national average baseline (i.e. the ‘natural’ background level in soils) value for cadmium of 0.16 mg/kg, consistent across all regions and soil types. The current national average concentration for cadmium across all agricultural land classes is 0.35 mg/kg with a range of 0-2.52 mg/kg.

The cadmium content of agricultural soils will vary from region to region depending on history of phosphate fertiliser, dominant land use, soil type, climate, sampling depth and bulk density.

Land-use is a key driver of topsoil cadmium concentrations. Cropping, pasture and horticulture land-uses all have higher concentrations of cadmium in soil than background, 'natural' land (e.g. conservation estate or other non-farmed land). The reason for this is almost certainly the application of phosphate fertiliser in most agricultural and horticultural land use.

Land used for dairying has the highest national average for cadmium concentration (0.73 mg/kg). Kiwifruit (0.71 mg/kg), berries (0.68 mg/kg), orchards (0.66 mg/kg), market gardening (0.46 mg/kg), beef farming (0.42 mg/kg) and unspecified drystock pasture (0.40 mg/kg) were also above the national average. Cropped soils appear to be mostly below the national average of 0.35 mg/kg for cadmium; however, these soils are tilled to a greater depth (20 cm) than other land-uses, and dilution decreases the cadmium concentration. Soils where tobacco was grown in the past were more elevated in cadmium (0.34 mg/kg) than other cropping soils. Sheep farming was slightly below (0.33 mg/kg) the national average. Sites receiving little or no fertiliser had the lowest cadmium concentrations (unfertilised 0.19 mg/kg, plantation forestry 0.14 mg/kg, native forest 0.10 mg/kg).

Results from the analysis of national data were broken down according to regional council regions. The region with the highest average cadmium concentration was Taranaki (0.66 mg/kg). Other regions with similar cadmium concentrations include Waikato (0.60 mg/kg) and Bay of Plenty (0.52 mg/kg). Dairy farming with a historically higher use of phosphate fertiliser is traditional in these areas and the soils of these regions have a high propensity to accumulate cadmium according to the Fertiliser Manufacturers' Research Association (NZFMRA) cadmium model. The regions with the lowest cadmium average concentrations were Canterbury (0.17 mg/kg), Gisborne (0.20 mg/kg), Manawatu-Wanganui (0.17 mg/kg), Nelson-Marlborough (0.23 mg/kg), Otago (0.20 mg/kg), Southland (0.21) and Wellington (0.20 mg/kg), all historic sheep farming areas.

Projections of future soil cadmium levels

An initial estimation of future topsoil cadmium concentrations was carried out using the Fertiliser Manufacturers' Research Association CadBal model and the national data summarised above. Results showed Brown Grey Clay Loams, Yellow Brown Loams and Yellow Brown Podzols soils accumulated more cadmium than the other soil types while alluvial, Yellow Brown Earths and Yellow Grey Earths soils accumulated the least cadmium. Differences in soil type cadmium accumulation appear due to differences in leaching losses and soil bulk densities input to the model.

In the model, sampling depth was related to cadmium concentrations. For example, increasing the sampling depth from 0–7.5 to 0–10 to 0–20 cm was shown to reduce the cadmium concentration from 0.43 mg/kg to 0.37 mg/kg to 0.26 mg/kg for a Yellow Brown Earth under dairy farming receiving 30 kg P $ha^{-1}y^{-1}$. However, available field measurements suggest that in some soils, the decrease in concentration with depth is not as marked as suggested by the model. Average concentrations in 63 Waikato soils only dropped from 0.66 mg/kg in the 0-10 cm layer to 0.57 mg/kg at 0-20 cm.

The model also showed pastoral farming resulted in increased soil cadmium content in all regions and nationally. The peat soils of the Waikato region showed the highest potential for cadmium accumulation - although this could in part be due to the low bulk density of these soils not being taken in account in the model. The regions with the highest present-day soil cadmium content also have the highest potential to accumulate cadmium in the future. Sheep/beef farming led to more accumulation of cadmium than dairy when both are under the same fertiliser regime although, in practice dairy farming requires more fertiliser for optimal production than beef and sheep farming. The difference in potential accumulation was due to the difference in the rates of soil loss (sedimentation loss) - 900 kg ha^{-1} y^{-1} for dairy farming and 500 kg ha^{-1} y^{-1} for sheep and beef. However, sedimentation losses are due to a range of factors including topography, soil type, leaching class and climate, not just farm type, and this result should be interpreted with caution.

Cadmium levels in soils under dairy farms were shown to decrease in cadmium with time once soil cadmium exceeded about 1.3 mg kg^{-1} due to removal of sediment, erosion products and leaching. This result is thought to be an artefact of the model, but if validated by empirical observation, may have important implications for farm sustainability and its accuracy should be further investigated.

Historically, the average rate of cadmium accumulation in New Zealand soils is estimated to be 6.6 µg/kg/yr. Loading estimates (allowing for losses) suggest that the current accumulation rate may be about two thirds of this figure, or 4.3 µg/kg/yr. Such a reduction would be consistent with the effect of the voluntary industry limit for cadmium in phosphate fertiliser of 280 mg/kg P, which was introduced from 1997.

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Chapter 4: Assessment of risk to human health

Cadmium and potential health impacts

The two main ways that cadmium can be absorbed by the human body are by ingestion and inhalation (eating and breathing) (Guy *et al*, 1999). Cadmium is much more readily absorbed by the lungs than through the gastrointestinal tract. However, other than cigarette smoking, substantial cadmium inhalation is rare, and usually occurs only in industrial settings. Cases of both chronic and acute cadmium poisonings have occurred among people involved in the welding, soldering or cutting of cadmium alloys or metals containing cadmium (Schulte-Schrepping & Piscator, 1985). Cadmium poisoning from dietary sources is rare, and has also been largely linked to the industrial use of cadmium, rather than agricultural activities such as fertiliser use.

For the majority of people not exposed to cadmium through working in heavy industry, cadmium exposure occurs at low levels from environmental sources throughout their lives. Most of the cadmium absorbed by the average person comes from food (over 90%), with only small amounts coming from air, water or other sources. The exceptions are smokers. Kidneys of smokers generally contain twice as much cadmium as those of non-smokers, indicating that in smokers, the intake from cigarettes can equal or exceed the intake from food (Schilte-Shrepping & Piscator, 1985).

Both acute and chronic cadmium exposure can have effects on health. Acute cadmium poisoning can cause death. Chronic, long-term exposure affects the kidneys, liver, lungs and bones. Continued, low level exposure to cadmium (chronic exposure) leads to accumulation in the liver and kidneys. Therefore, the amount of cadmium stored in the body increases with age. Once cadmium levels in these organs reach a particular level, damage and dysfunction occurs. To date, in most members of the population, these thresholds are never reached before death occurs from other causes.

Current management of food safety risks from cadmium

Responsibilities for food safety

Food safety standards include the protection of the New Zealand population from unsafe cadmium exposure from food. Two organisations share the primary responsibility for protecting consumers: New Zealand Food Safety Authority (NZFSA) and Food Standards Australia New Zealand (FSANZ). FSANZ develops food standards for contaminants for both countries, with advice from NZFSA, based on rigorous scientific assessment of risk to public health and safety. In New Zealand, NZFSA enforces these food standards for domestically consumed food. In relation to cadmium management, these agencies include monitoring cadmium levels in average New Zealanders' diets, and primary animal products under the Animal Products Act and the Joint Food Standards Code thresholds.

Food safety measures

Dietary exposure guidelines for contaminants

Guidelines for acceptable dietary exposure to chemicals are usually expressed either as the Acceptable Daily Intake (ADI) (NB in New Zealand the term Acceptable Daily Exposure (ADE food) is used) or the Provisional Tolerable Weekly Intake (PTWI). The ADI (or ADE food), which is commonly used for registered agricultural compounds that are managed by Good Agricultural Practice, is defined as “an estimate of the amount of a substance in food or drinking water, expressed on a body-weight basis, that can be ingested daily over a lifetime without appreciable health risk”.

The PTWI is more commonly used for contaminants with cumulative properties. The PTWI is set according to the best available current science, and represents the upper level of a substance that can be safely consumed over a lifetime without observable health effects.

In 2003, the Joint FAO/WHO Expert Committee on Food Additives (JECFA) confirmed a previous evaluation, setting a Provisional Tolerable Weekly Intake (PTWI) for cadmium of 7 µg/kg body weight/week for adults (WHO, 2004). It should be noted that the above international PTWI is provisional, and there is a possibility that this figure may be revised in the future as scientific research into cadmium progresses.

Regulatory limits for contaminants

In New Zealand, there are two regulatory limits that may apply to cadmium in food: the Maximum Levels (MLs) of Standard 1.4.1: Contaminants and natural toxicants, which is issued under the Joint Food Standards Code ; and the Maximum Permissible Levels (MPLs) of the Animal Products (Residue Specifications) Notice, 2004, which is issued under the Animal Products Act 1999.

Maximum Levels (MLs): As a general principle, regardless of whether or not an ML exists, the levels of contaminants and natural toxicants in all foods are expected to be kept As Low As Reasonably Achievable (the ALARA principle). Although contaminants and toxicants may be present in a wide range of foods, an ML is established only where it serves an effective risk management function and only for those foods that provide a significant contribution to the total dietary exposure.

Generally Expected Levels (GELs), are established to complement the use of MLs. GELs, while not legally enforceable, provide a benchmark against which to measure contaminant levels in foods. No GELs have been established for cadmium that are applicable in New Zealand.

Maximum Permissable Levels (MPLs): MPLs set under the Animal Products Act are another tool for managing risks to human health arising from substances in food. They perform the additional function of providing the controls and mechanisms needed to give and to safeguard official assurances given by NZFSA (on behalf of the New Zealand government) to foreign governments for entry of New Zealand products into overseas markets.

Maximum Residue Limits (MRLs): Some countries regulate contaminants through Maximum Residue Limits (MRLs). An MRL is set having regard to Good Agricultural Practice, which incorporates consideration of amongst other things efficacy, safety, welfare (to animals), optimal use patterns and also total dietary exposure to the substance and thus has limited application to cadmium in this context.

Exceedences of food standards

From time to time, an ML or MPL may be exceeded in a particular food product. This almost never means that the food product in question is unsafe to eat. This is because these food standards have a large built-in safety margin. In regards to cadmium, adverse health impacts through dietary exposure, if they occurred, would generally do so after a lifetime of significantly high dietary intake of cadmium. This is why, when it comes to monitoring food safety in regards to cadmium, the Provisional Tolerable Weekly Intake is the most important measure.

Maximum Levels, on the other hand, act as a ‘trigger’, indicating that further investigation is needed into agricultural practices on the property in question and may result in regulatory action.

If a ML for cadmium is exceeded, it does not necessarily indicate that the food product has not been produced in accordance with Good Agricultural Practice as might be the case with an agricultural compound. This is because cadmium occurs in the environment, and is not under such direct control of the farmer, as agricultural compounds such as veterinary medicines are. Nor should it be concluded that food grown in soil that exceeds the 1 mg/kg guideline is unsafe to eat.

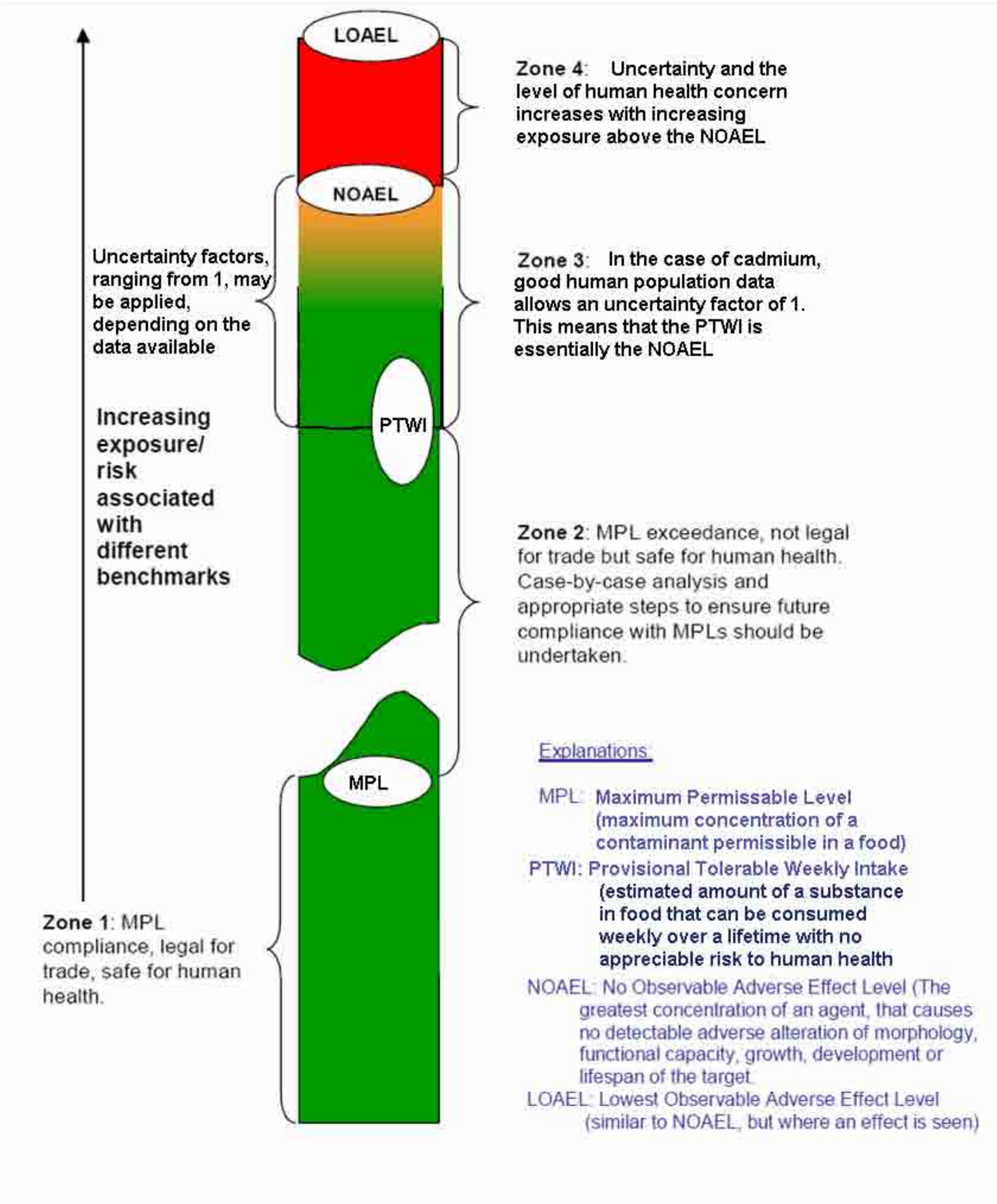
Exceedences of the MRL do require an investigation of the circumstances which may result in a number of risk management measures being applied such as a review of the applicable MLs, advice on food consumption, changes to land use recommendations, research into or adoption of cadmium sparing plants, use of DAP for certain crops.

In New Zealand, it is not considered appropriate to manage cadmium in the diet by measuring food against MRLs, because MRLs are normally applied to the active ingredients of registered products used in agriculture, such as pesticides and veterinary medicines.

For contaminants such as cadmium, the relationship between fertiliser application, soil levels and cadmium residues that appear in food is complex. Cadmium is naturally present in some phosphate fertilizers required for the necessary production of food and thus to a great extent is outside the control of the farmer. Notwithstanding that, food exported from New Zealand is required to meet any regulations set by the importing country. Food product lots which do not are likely to be rejected.

Below is a schematic diagram showing relationships between various terms used in food safety Figure 4.1.

Figure 4.1: Relationship between the various regulatory settings for food standards.



New Zealanders' current dietary exposure to cadmium

Findings from the New Zealand Total Diet Survey

One of important ways that the New Zealand Food Safety Authority monitors dietary exposure is by contaminants monitoring through the New Zealand Total Diet Surveys (NZTDS). The NZTDS takes a selection of typical New Zealand dietary food items, and test them for a wide range of agricultural compounds, environmental contaminants, cadmium included and some nutrients. Each NZTDS is a four year project carried out every 5 or 6 years.

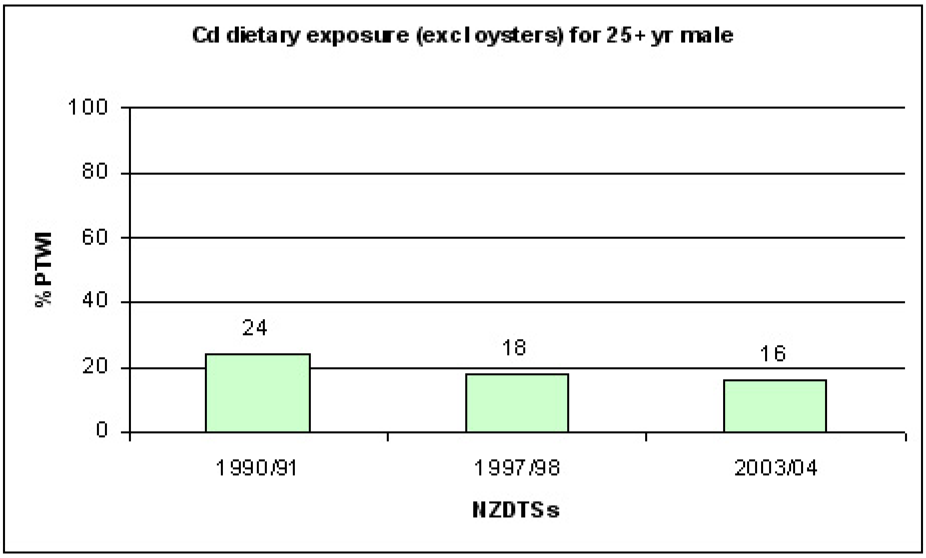
The main finding of the 2003/04 New Zealand Total Diet Survey (NZTDS) in respect of cadmium was that the estimated weekly exposure to cadmium in the average New Zealand diet was well within the Provisional Tolerable Weekly Intake (PTWI) (Vannoort & Thomson, 2006). The New Zealand Food Safety Authority (NZFSA) has therefore concluded that the cadmium dietary exposures found in the NZTDS are highly unlikely to have any adverse health implications for the New Zealand population (Vannoort & Thomson, 2006).

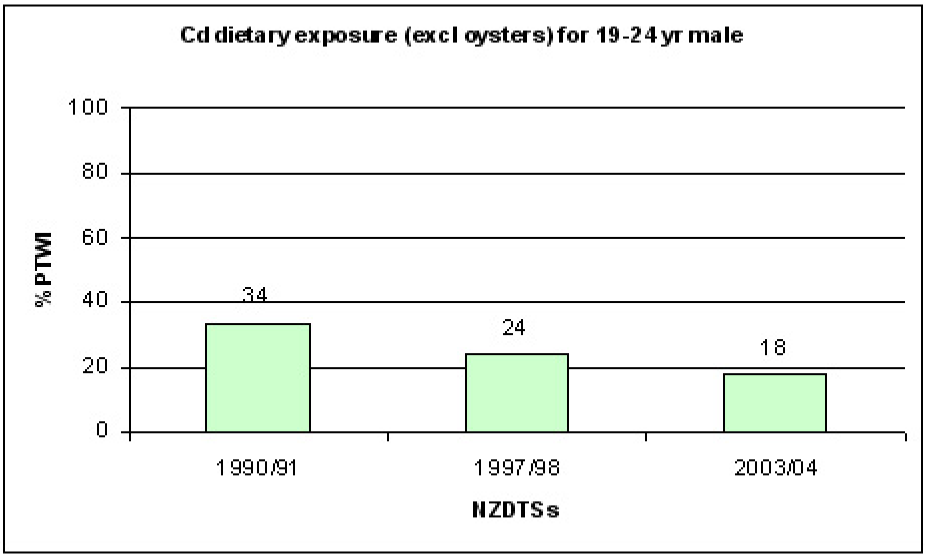
It should be noted that NZTDS focuses on average consumers. High or extreme consumers of some foods may have significantly higher or lower dietary exposures depending on how much their diet differed from the normal.

According to the 2003/04 survey, estimated weekly dietary intake of cadmium for all age-sex groups are well below the PTWI. These exposures range from 18% of the PTWI for the 19-24 year old male (on a diet without oysters) to 37% for the 5-6 year old child and 1-3 year old toddler (Vannoort & Thomson, 2006). The higher percentage of the PTWI consumed by infants is thought to be due to their low body weight ratio to weight of food eaten. The higher percentage of the cadmium PTWI shown in the diet of infants and young children decreases with age.

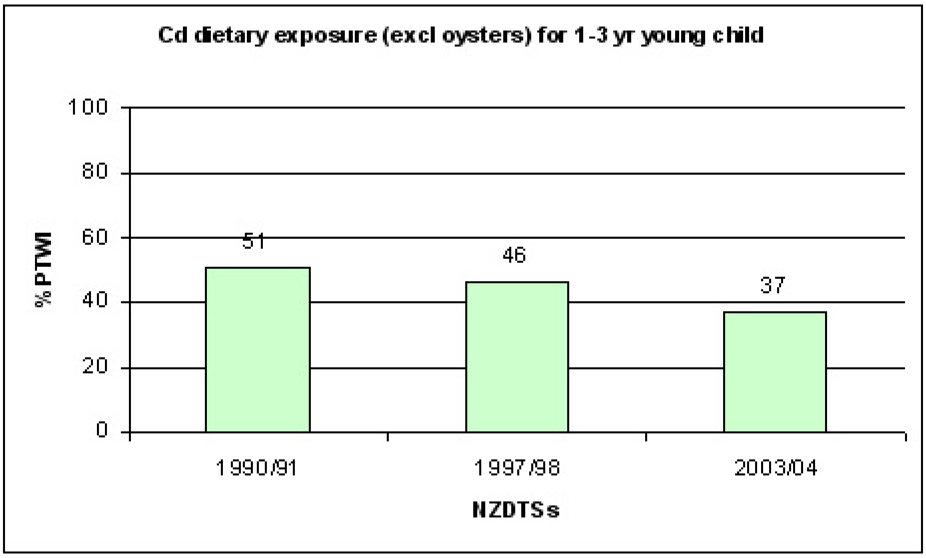
The percentage of the PTWI for cadmium exposure, as identified by the NZTDS, has generally been decreasing since 1982. This finding may be due to decreasing dietary cadmium intake but could also be due to changes in the NZTDS methodology relating to the level of detection and the number of samples analysed. However a review of dietary exposure correcting for different analytical methodology for the last three NZTDS's also show a declining cadmium exposure.

Figure 4.2 Estimated dietary exposure to cadmium for different age groups as a proportion of PTWI (Source: Vannoort & Thomson, 2005)





Cd dietary exposure (excl oysters) for 19-24 yr male
100
80
60
40
20
0
% PTWI
34
24
18
1990/91
1997/98
2003/04
NZDTSs



Cd dietary exposure (excl oysters) for 1-3 yr young child
100
80
60
40
20
0
% PTWI
51
46
37
1990/91
1997/98
2003/04
NZDTSs

Figure 4.3: Estimated weekly dietary exposure to cadmium for the eight age-sex groups of the 2003/04 NZTDS, for simulated diet or simulated diet excluding oysters (Source: (Vannoort and Thomson, 2005)

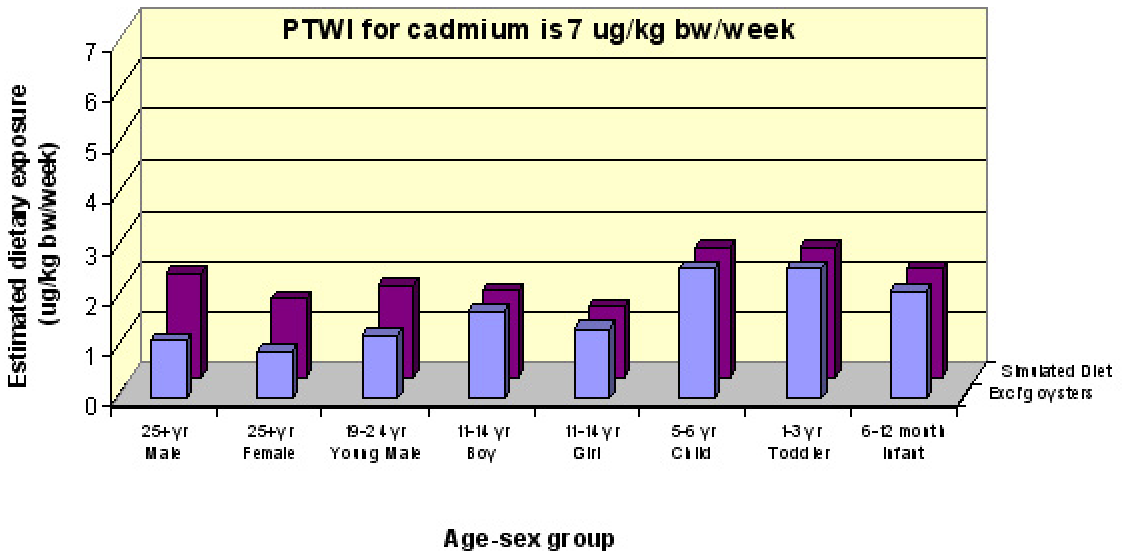
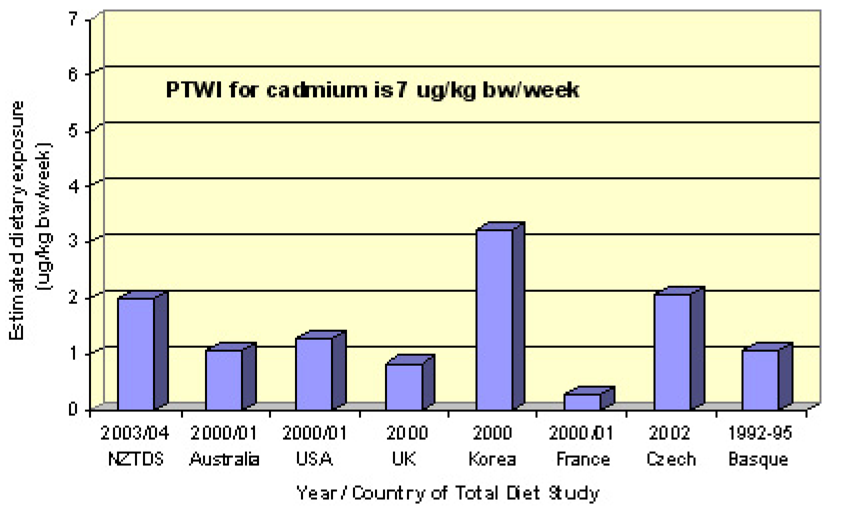


Figure 4.4 below compares the 2003/04 NZTDS estimated weekly dietary exposure to cadmium for a 25+ year male (2.0 µg/kg bw/week) with those from total diet surveys of Australia, the USA, the UK, the Republic of Korea, France, the Czech Republic and the Basque Country. The cadmium exposure from foods in Australia, USA, UK, and the Basque Country are all lower than in New Zealand. The Czech Republic has an almost identical dietary exposure for its 18+ year male. Of the other countries considered, France reported the lowest weekly cadmium dietary exposures, while the Republic of Korea reported the highest (Vannoort & Thomson, 2005).

Figure 4.4: Comparison of estimated weekly dietary exposure to cadmium for a 25+ year male in the 2003/04 NZTDS with overseas studies (Source: Vannoort & Thomson, 2005)



As most non-smokers' main exposure to cadmium is through food, and taking into account the country of origin, the level of exposure to cadmium through food in the average New Zealand diet (as measured in the 2003/04 NZTDS) is highly unlikely to cause health impacts.

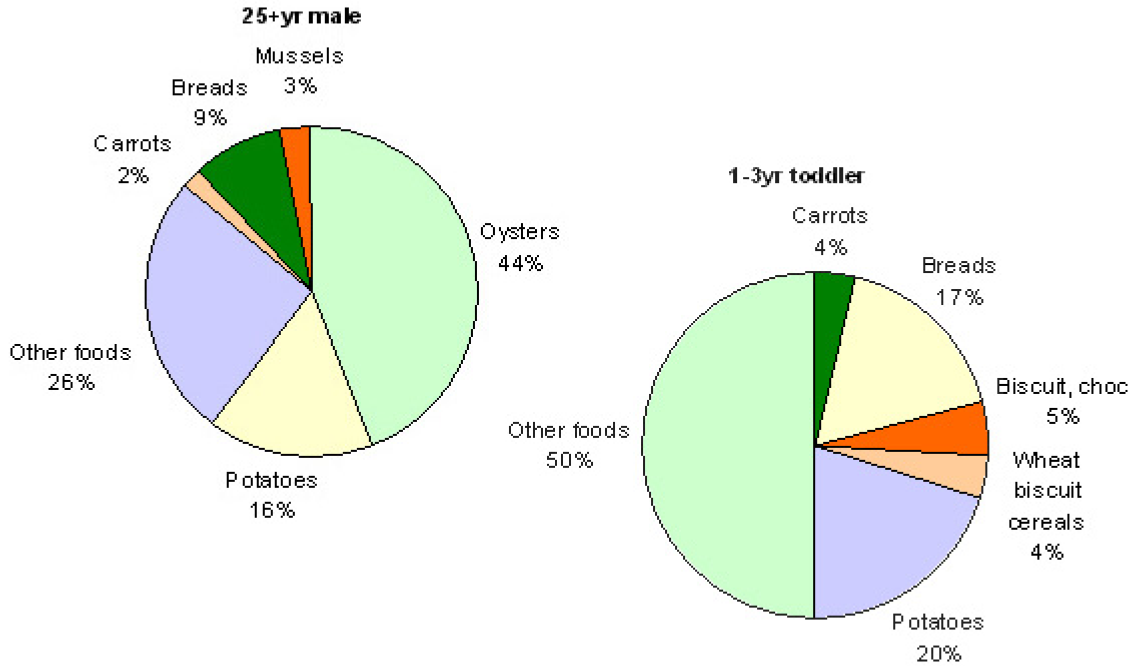
NZTDS findings on cadmium levels in food products

The levels of cadmium found in the 2003/04 NZTDS foods were generally consistent with internationally documented levels (WHO, 1992a; Jensen, 1992). New Zealand dietary exposure sources are not dissimilar to those in other countries surveyed. That is, natural cadmium in soil, or applied as fertiliser are thought to be the main contributing sources.

The 2003/04 NZTDS confirms that the contribution from oysters (44%) dominates dietary cadmium exposure for the 25+ year male. The cadmium content of New Zealand shellfish is probably of natural occurrence. Widely variant oyster cadmium levels (0.12 mg/kg - 7.9 mg/kg) have been encountered in New Zealand, dependant on the sampling location. However research from Otago medical school found no adverse health effects due to abnormally high intakes of cadmium from oysters.

Potatoes and related products (16%), all breads (9%), mussels (3%) and carrots (2%) are the other specific foods which contribute significantly to dietary cadmium exposure of the 25+ year male. Cocoa, and related products such as chocolate and chocolate biscuits, are also well recognised as a potential source of cadmium (Stenhouse,1991; Vannoort and Thomson, 2005). Thus only five specific foods, of the 121 representative foods analysed in the NZTDS, contribute 74% of the weekly dietary cadmium exposure of the 25+ year male.

Figure 4.5: Specific foods which contribute to estimated dietary exposure to cadmium in a 25+ year male and a 1-3 year toddler in the 2003/04 NZTDS



Chapter summary

Dietary cadmium can lead to both chronic and acute adverse health impacts, depending on the level consumed. The New Zealand Food Safety Authority monitors and manages the levels of contaminants in the diets of New Zealanders. The Provisional Tolerable Weekly Intake (PTWI) is commonly used to measure dietary exposure to cumulative contaminants such as cadmium, and represents a level of a substance which can be consumed on a weekly basis over a lifetime with no appreciable risk.

It is the New Zealand Food Safety Authority's assessment that the cadmium dietary exposures found in the 2003/04 New Zealand Total Diet Survey are highly unlikely to have any adverse health implications for the New Zealand population. The estimated weekly intake of all age-sex groups surveyed was well below the PTWI and has generally been decreasing since 1982 (Vannort & Thomson, 2006).

Cadmium levels found in the food products surveyed were generally consistent with internationally documented levels (WHO, 1992a; Jensen, 1992). Oysters were a significant contributing source of cadmium in those simulated diets which included oysters. Other food products which contributed significantly to the overall weekly dietary cadmium intake were bread and other wheat products, carrots, cocoa and potatoes.

As most non-smokers' main exposure to cadmium is through food, and taking into account the country of origin, the level of exposure to cadmium through food in the average New Zealand diet (as measured in the 2003/04 NZTDS) is highly unlikely to cause health impacts.

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Chapter 5: Assessment of risk to export trade and economy

Introduction

If cadmium were to accumulate in New Zealand soils to a point at which food produced on those soils began to regularly breach food standards, both domestic and export sales of those food products would be compromised. As a nation heavily dependent on agricultural exports for its economic wellbeing, such a scenario could potentially be serious for New Zealand.

Besides the direct risks of exceeding food standards for cadmium, there are also indirect risks relating to the potential for harm to New Zealand's 'clean, green image', and for private sector initiatives which could hinder exports on the basis of cadmium levels, such as standards set by supermarkets or quality assurance schemes.

It is difficult to estimate the likelihood of cadmium accumulation leading to food standard breaches in New Zealand, because of:

- a lack of comprehensive data on current and projected future soil cadmium levels; and
- uncertainties in our understanding of the extent to which increasing soil levels of cadmium may translate to higher concentrations in various types of produce.

Assessment of risk factors to agricultural trade

There are several factors which are likely to influence the level of risk to New Zealand's agricultural economy from cadmium:

- The current levels of cadmium in agricultural soils, and the rate of accumulation;
- The uptake of soil cadmium by different plant products;
- The economic significance of the products potentially affected; and
- The markets to which these at-risk crops are exported and the sensitivity of their governments, regulatory authorities and food retailing sector or consumers to cadmium issues.
- The magnitude and direction if any modifications of the current Cd limits decrease in the future

Classification of land as contaminated and meeting the definitions as per the RMA

Current levels and accumulation rate of cadmium in agricultural soils

Levels of cadmium in plants and animals grazed or grown on those soils are generally related to the cadmium in those soils but with complicating factors. New Zealand agricultural soils in general show elevated soil cadmium levels compared to unmodified, 'background' levels, and existing research points towards ongoing cadmium accumulation in those soils which receive continued applications of superphosphate fertiliser. The rate of cadmium increase will be determined by the ongoing application rates of superphosphate.

Given these trends, it can be assumed that if soil cadmium levels continue to increase over time, the level of cadmium in specific agricultural products will increase without intervention. This increase of cadmium in products may lead to exceedences of food standards in the future.

There is much uncertainty as to how, when, where and at what rate such exceedences might occur and what impact if any they might have on trade (See Chapter 3 for further information on current soil cadmium levels and accumulation). However, with an overall average soil cadmium level of 0.35 mg/kg, it seems unlikely that soil cadmium levels in New Zealand would commonly lead to food standard breaches any time in the near future. Areas which are at or exceed the top-end of the range for soil cadmium could start to see occasional exceedences in specific crops.

Potential impacts on different agricultural products

Agricultural products and their sensitivity to soil cadmium

Agricultural products differ in the extent to which they uptake soil cadmium. Many agricultural products are not affected by cadmium accumulation in soil either because they are not food products, or are not grown directly on soil (e.g. wool, leather, honey, hydroponically-grown produce).

Those products which may be affected differ greatly in the extent to which they are sensitive to cadmium levels in soil. Animals store cadmium in their liver and kidneys, therefore, muscle meat and dairy products have low cadmium levels, although offals are sensitive to cadmium intake levels. This is significant given the size of New Zealand's dairy and meat sectors, which would remain unaffected even in the face of significant accumulation of cadmium in soils.

Although liver and kidneys are sensitive to soil cadmium levels, because cadmium builds up in an animal's body over time it is relatively easy to manage cadmium levels in offals simply by discarding offals from animals over a particular age. New Zealand already has an offal discard policy; kidneys from animals older than 30 months are not eligible for human consumption and must be discarded. This has the potential to be raised or lowered according to trade considerations. It should be noted, however, that the discard of offals does represent a loss of revenue. In general, while an offal cadmium risk is potentially present, an effective risk management procedure is in place to maintain the risk at an acceptable level.

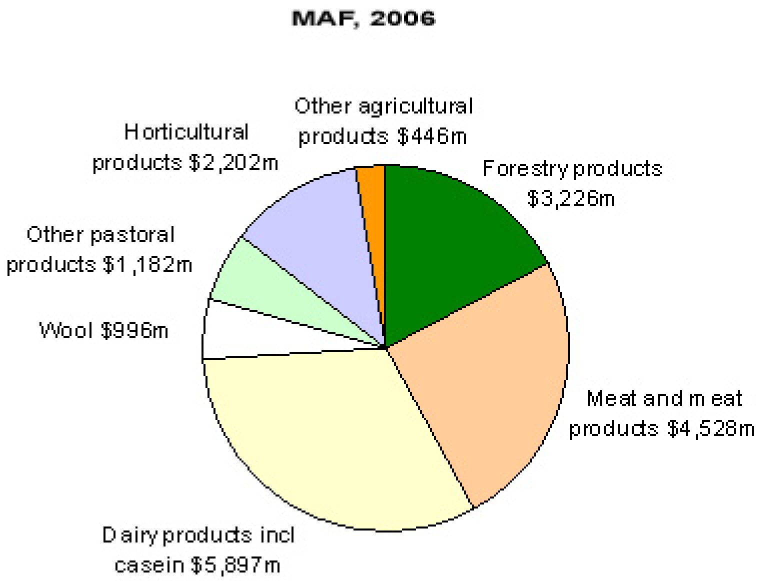
Different horticultural crops would also be affected differently by high soil cadmium levels. This is because plant species vary greatly in their ability to absorb cadmium from the soil. In general, when grown in the same soil, cadmium accumulation by different plant species has been shown to decrease in the order leafy vegetables > root vegetables > grain crops > fruit (Grey et al, 1999, p 473). Different cultivars vary widely in their uptake of cadmium (a point often overlooked by plant breeders) and cadmium concentrations may differ between different parts of the same plant.

Based on limited data available, it is possible that between 1-2% of selected tuber and leafy vegetables in New Zealand may exceed current food standards (Roberts AHC *et al* 1995, Gray CW *et al* 2001, Loganathan, P *et al,* 2003). Published information suggests the existence of a similar problem in Australia (McLaughlan *et al*., 1997; Jinadasa *et al*., 1997).

Economic significance of agricultural products potentially affected

In the year ending June 2004, agricultural, forestry and horticultural exports were valued at $18.5 billion or 65% of New Zealand's total exports (see figure 5.1 below). Dairy earns the lions share,($5,897 million, 2006) followed by meat products ($4,528 million, 2006), forestry ($3,226 million, 2006) and horticulture ($2,020 million, 2006).

Figure 5.1 Profile of New Zealand agricultural export products and value for 2004

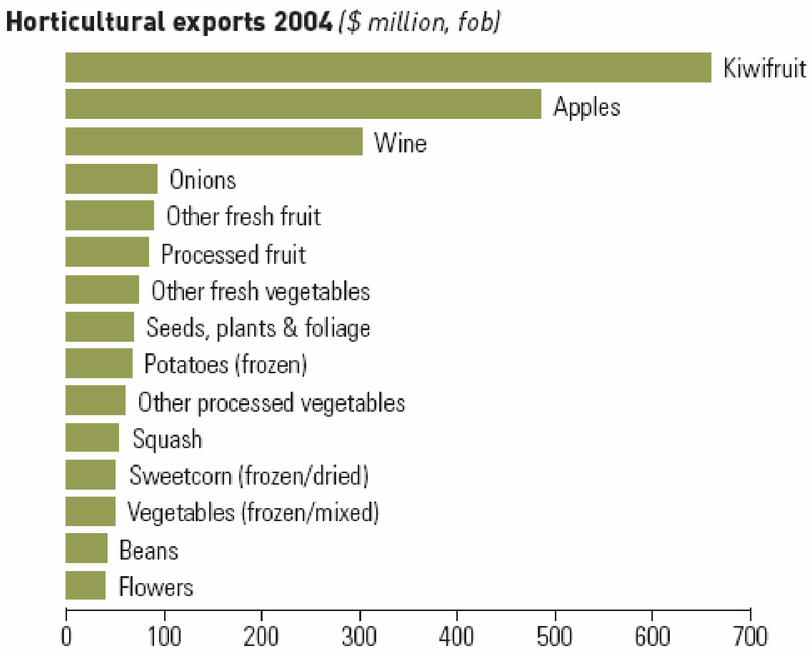


Importantly New Zealand’s key agricultural exports such as dairy, meat, forestry, wool, kiwifruit, apples, wine and other fresh and processed fruits would be unlikely to be affected by any cadmium accumulation in soils.

Any future elevation in soil cadmium levels is likely to affect parts of the vegetable industry and sales of offals (although this can be managed with different targeted discard criteria if required).

New Zealand produces more than 50 different types of vegetables, which are sold either fresh or processed. New Zealand’s fresh and processed vegetable sales are worth approximately $1.3 billion per annum ($866 m domestic and $484m exports) (HortResearch, 2004). Looking at the export sales values of vegetables in the figure below, we can see that onions, squash are the major fresh vegetable exports, while potatoes, sweet corn, mixed vegetables, and beans are the major processed and frozen vegetable exports.

Figure 5.2: Profile of New Zealand horticultural exports by product and value for 2004



Offals

As discussed in earlier sections, cadmium is predominantly stored in the liver and kidneys of animals, and so a significant increase in soil cadmium levels could be expected to result in elevated levels of cadmium in liver and kidneys.

However, the vast majority of New Zealand sheep are slaughtered at less than 30 months, an age too young to generally have accumulated significant amounts of cadmium. Of approximately 29 million sheep slaughtered, over 26 million of these are lambs and will be less than 18 months old. Seventy-five percent of the export value of offals are from lamb liver. Lambs are always slaughtered at a young age, meaning that the risk of lamb livers (or kidneys) exceeding cadmium standards is negligible. While offals from older animals may be collected, for commercial reasons often they are not.

The risk of food standard exceedences is limited only to the small number of kidneys and livers from the upper end of the range for kidney acceptance for human consumption.

Sales of kidneys and livers make up a relatively small proportion of New Zealand's trade in meat products (approximately $14 m out of a total of $4.6 b in the year ending December 2005. Somewhat less than 1 % of offals are expected to exceed the NZ ML. As Codex Alimentarius Commission (CAC) has not specified an MRL for cadmium for ruminant offals, those countries that accept CAC as the international trade standard would have no issue with the current cadmium status of New Zealand offals.

New Zealand's export markets and market sensitivity

Food standards and market access

New Zealand crops grown for export must meet domestic food standards and also those of New Zealand's trading partners. Market access for exported products requires compliance with importing countries' food standards, which include Maximum Residue Levels (MRLs).

As stated earlier, MRLs are a measure of Good Agriculture Practice that is, monitoring whether agricultural compounds are used on farms in the best possible way. Non compliance with an MRL would therefore be expected to result in an investigation of farming practices. MRLs were not intended to be a measure of food safety directly, although that is often how they are used in practice (i.e. food products exceeding an MRL will be rejected as unfit for consumption, even though the very large safety margins built into the measure mean that food products that exceed an MRL would be safe).

Countries' MRLs are commonly based on the international food safety standards developed by the Codex Alimentarius Commission (Codex). However, in accordance with the World Trade Organisation's (WTO) Agreement on the Application of Sanitary and Phytosanitary Measures (the 'SPS Agreement'), countries have the right to set more stringent standards provided these are scientifically justifiable.

Countries normally determine compliance with MRLs by testing products at the port of entry. This testing is random; not every consignment is tested. If a product is found to exceed an MRL or other food standard it may not be accepted and there will be an associated economic loss for New Zealand producers.

Corresponding testing also takes place in New Zealand under the Animal Product Act or other export requirements to offer foreign markets assurance that their requirements are met. It is a foremost requirement that all exported food products meet the New Zealand Regulatory requirements. Testing is done in New Zealand primary to provide assurance that the control systems are working as required and to allow early intervention and corrective actions to be applied when non-compliant product is detected. Official assurances are made on behalf of nearly all edible animal products but certificates may not necessarily specifically reference cadmium

There is an expectation that regulatory thresholds for contaminants such as cadmium, should be set at a level to protect the consumer without unnecessarily restricting trade. Some of New Zealand's trading partners are more industrialised and, consequently, have higher rates of industrial cadmium exposure (e.g. atmospheric emissions), and greater overall exposure to cadmium from all sources. For economic and other reasons, such countries may choose to regulate chemical residues and contaminants in food, rather than the industrial sources of cadmium. The resulting food regulatory thresholds are likely to be lower than those of New Zealand, and may appear overly conservative and trade-restrictive from a New Zealand perspective.

For these and other reasons, food standards can differ between countries. The table below gives the MRLs for cadmium for various products in Australia and New Zealand compared with levels set for the EU for example.

Table 5.1: MRL levels for various products in Australia and NZ and the EU

Product	MRL for Cadmium mg/kg	
	Australia and NZ	EU
Liver of cattle, sheep and pig	1.25	0.5
Kidney of cattle, sheep and pig	2.5	1.0*
Leafy vegetables	0.1	0.2

* The EU includes poultry kidneys in its standard.

The WTO and the international trading environment

The international trading environment is, to a significant extent, regulated by the WTO and the trade agreements that it administers. The WTO aims to provide a single institutional framework for the global trading system, based on the idea of freer, rules-based trade which will help producers of goods and services, exporters, and importers conduct their business. The WTO agreements have been negotiated and signed by the majority of the world's trading nations and ratified in their parliaments (WTO, 2006). The WTO agreement relevant to the consideration of cadmium is the SPS Agreement. The SPS agreement relates to domestic standards or regulations for the protection of human, animal or plant health, such as food safety (Bureau of Resource Sciences, 1997).

Under the SPS Agreement, WTO Members commit to harmonising their sanitary and phytosanitary measures, by following existing international guidelines and standards, such as those set by Codex for food safety (Bureau of Resource Sciences, 1997). Within the SPS Agreement, national standards exceeding internationally established ones are permitted in the presence of scientific justification. Any measures established for food safety reasons must be based on sound science, transparent, applied consistently without discrimination, and limited only to those measures which are necessary to protect human, animal or plant health (Bureau of Resource Sciences, 1997).

International trade rules may mitigate a potential risk which could face the agricultural sector resulting from cadmium accumulation in soils. The WTO agreements are likely to dissuade most countries from attempting to penalise New Zealand agricultural imports to compensate for their domestic cadmium regulations. The WTO does not generally permit trade measures to be established for 'process and production methods' (i.e. the conditions or way in which a product is produced). This means that agricultural products which otherwise meet food safety standards should not be rejected on the basis of on-farm conditions, such as soil cadmium levels. These principles mean that it would be unlikely, although still possible, for New Zealand's trading partners to put trade measures in place to regulate the cadmium levels in soil in which imported food is produced, or the levels of cadmium in fertilizer used. Some countries notably the European Union have made recent moves in this direction but the extent to which this trend may affect New Zealand food exports is uncertain

It should be noted, however, that the WTO system applies only to action taken by the governments of member countries, not those taken by the private sector. Therefore, they would not provide any assistance if New Zealand was to face arbitrary or unscientific trade measures from food retailing networks or non-government schemes such as the Euro Retailer Produce Working Group on Good Agricultural Practice (EUREP-GAP).

Consumer-driven and non-government requirements which influence export trade

There is a risk that cadmium accumulation could affect the perceptions of consumers overseas, and taint the image of New Zealand agriculture and food exports.

Increasingly, market forces and industry-led initiatives are driving food safety and quality assurance measures to manage contaminants in food. Underlying industry-led initiatives is consumer concern about the safety or environmental attributes of food products. These concerns are leading to new standards and requirements set by major overseas food retailers or non-governmental organisations. Many large retail chains, particularly in 'high-end' markets such as Europe, are now insisting on strict environmental standards, including particular farming standards, as a condition of doing business (PCE, 2004).

The influence of major supermarkets has risen dramatically in recent years, and they now can exert a significant amount of control over the supply chain for agricultural products. In the

United Kingdom, four supermarket chains make 70% of all food and household good sales (PCE, 2004). Major food retailers are increasingly able to act as ‘market gatekeepers’, and the standards and conditions they insist upon can become, in effect, just as much of a factor regulating international trade in agricultural products as the ‘official’ Codex standards.

One organisation aimed at providing assurances to customers is the Euro Retailer Produce Working Group (EUREP), which includes the leading supermarkets in Europe, which launched its protocol on Good Agricultural Practice (EUREP-GAP) for horticultural products in 1999. EUREP-GAP has developed auditable standards to provide independent verification of minimum social, environmental and food safety standards throughout the supply chain. Other such non-government or private sector initiatives include the British Farm Standard, the Food Alliance in the United States and the Global Food Safety Initiative, which all provide independent certification safe and sustainable food production practices.

Thus, to secure international export markets, New Zealand producers must often meet not only international and national food safety standards (such as Codex standards and MRLs), but also commercial standards (such as EUREP-GAP). This adds to the complexity of food standards to which producers must adhere, and the pressure to keep cadmium levels in food to below international best-practice levels.

Summary of risk ‘hotspots’

Agricultural products and their risk from potential cadmium accumulation

No risk	**Low risk**	**Moderate risk**
Wool, leather and fibre	Dairy	Root vegetables
Forestry	Muscle meat	Leafy vegetables
Hydroponically-grown produce	Fruit	
Honey	Grains	
	Offals (because of age of animals supplying most of the offal trade)	

Risk estimation for the national economy

The short-term risk to New Zealand’s national economy from cadmium accumulation in soil is *low*. This is because if soil cadmium levels were to accumulate and no management action were taken, the effect on agricultural products would be largely confined to vegetables. Our major agricultural export sectors of dairy, wool, other pastoral and agriculture products would not be affected by cadmium accumulation occurring under current farming conditions.

Vegetables, which are more sensitive to elevated soil cadmium levels, made up about $0.5 billion of the $2.2 billion earned by horticultural exports. The $0.7 billion spent domestically on New Zealand vegetables can be added to this total. The vegetable sector, while an important earner for New Zealand, is not central to the New Zealand economy as a whole.

Risk estimation for the vegetable sectors

While the vegetable sector may not be the largest contributor to total value of exports in New Zealand’s economy, it is still a substantial sector. Vegetable growing occupies 50,000 ha of land in New Zealand, and employs 25,000 people (HortResearch, 2004). The impacts of any impediments to New Zealand’s vegetable exports would be hard felt.

The near-term risk of cadmium accumulation reaching levels at which MRLs are breached is taken as low, and the consequences for the vegetable sector of this occurring would be medium. That is, there would be some impact, but it would not be severe for the sector as a whole. Mitigation strategies would be available for those parts of the sector affected, such as growing crop species or varieties with low uptake of cadmium. Therefore the risk estimation for the horticulture sector is medium/low.

In the medium-term (assuming increasing soil cadmium levels over the next 20-50 years, raising the risk of breaching MRLs to medium), the risk to the vegetable sector would be medium. In conclusion, there are some strategic risks for the vegetable sectors in relation to cadmium. There are various management techniques, policies and strategies to mitigate these risks, which will be considered in the Cadmium Working Group's second report.

Chapter summary

If cadmium accumulated in soils to levels at which food produced on those soils began to breach food safety standards, both domestic and export sales of these food products would be compromised. New Zealand agricultural products for export must meet domestic food standards, and also those of export markets, which could be more stringent. .

In the short term the risk to the New Zealand economy is low. Any risks from significant accumulation of cadmium fall on a relatively small segment of the agriculture sector; mainly leafy and root vegetable producers and some offal from animals. Dairy (milk), muscle meat and fruit products are unlikely to be at risk on the basis of cadmium levels, due to the low capacity of these products to store cadmium. The New Zealand Food Safety Authority currently has a process in place that manages the risk posed by offal's containing high levels of cadmium.

Besides the direct low risk of exceeding food standards for cadmium in offal and some vegetables, there are also more 'indirect' risks, such as the possibility of New Zealand's standards for cadmium in soil or fertiliser falling behind those of our trading partners, with subsequent damage to our 'clean and green' reputation. These indirect effects could be played out in the private sector, for example, through large international food retailers which are increasingly insisting on more stringent standards for food safety, environmental performance and animal welfare as commercial conditions.

It would be useful to consider ways to mitigate these risks for producers who produce the small subset of commodities which could potentially be affected by cadmium accumulation in soil.

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Chapter 6: Assessment of risk to land use flexibility

What is the potential issue?

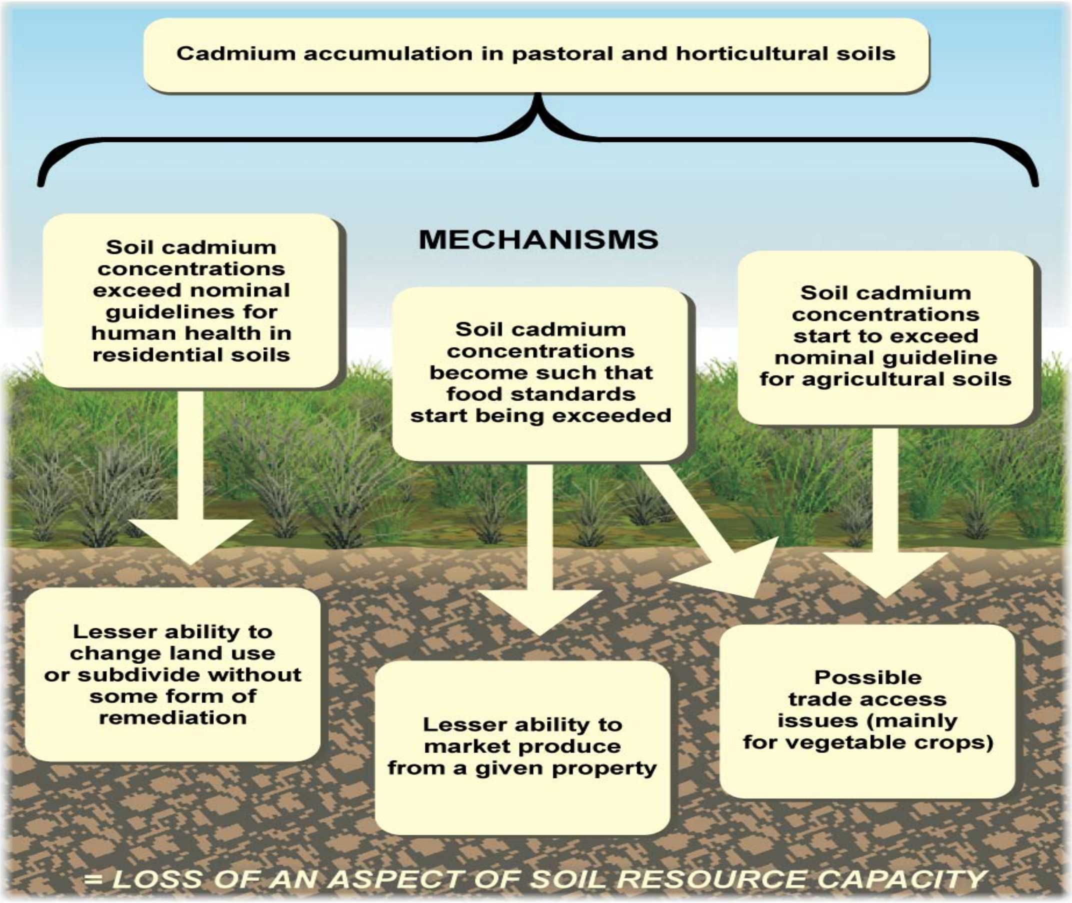
'Land use flexibility' is defined here as the ability to freely change the type of activity being carried out on a given property. Accumulation of some persistent trace contaminants in soils, such as cadmium, has the potential to reduce land use flexibility over time. This is because concentrations that are acceptable for one type of land use may prove to be too high for a subsequent 'more sensitive' use.

Cadmium accumulation could result in two main different forms of 'loss of land use flexibility':

Future inability to subdivide the land for residential or rural-residential purposes without some form of rehabilitation; and

Future inability to change between certain agricultural land uses, if the change was from producing a less cadmium sensitive food (e.g. dairy) to one that was more sensitive to soil cadmium levels (e.g. growing vegetables).

Figure 6.1: Mechanisms by which cadmium accumulation in productive soils may cause loss of land use flexibility



Acknowledge: Nick Kim, Environment Waikato

Risks to the future ability to subdivide

The role of soil guidelines and standards

Residential soil guidelines or standards are used by local authorities to assess the level of acceptability of certain soil contaminants, and can therefore define at what point land is considered to be 'contaminated' or unfit for residential subdivision. As with food, the land use flexibility issue in this case is not caused by any immediate risk, but compliance with a conservative regulatory limit, that is designed to ensure that long-term risks to humans and the environment are tolerably low. In general cadmium in broad-acre areas does not pose a risk to human health at the levels typically found in New Zealand pastoral soils. However such soils occasionally exceed some of the more conservative overseas guidelines designed for long-term (chronic) protection of human health.

In practice, local authorities do not have the capacity to assess all the properties in their own regions and areas. Rather, soil assessments are usually only requested when a significant change is proposed for a property, and where this change is one that requires regulatory oversight and may also involve soil contamination issues. This means that agricultural soils could exceed nominal guidelines for cadmium, but the issue wouldn't be picked up until the soil was tested as part of an assessment of suitability for subdivision.

Generally, soil guidelines or standards for cadmium and other heavy metals are more stringent for agricultural soils than for residential, as agricultural land is used expressly for growing food, whereas this is only an occasional part of normal residential activities.

Internationally, guidelines for cadmium in residential soils range from non-binding 'targets' of 0.8 mg/kg (Netherlands) to 20 mg/kg (Australia) and higher. In the absence of New Zealand guidelines or standards for soil cadmium, local authorities currently select from the range available, and may use the guidance provided in the Ministry for the Environment's Contaminated Land Management Guidelines No. 2. In general terms, this guidance directs local authorities towards the selection of the more conservative figures of the range available.

Table 6.1: Australian, United Kingdom, Canadian and Dutch risk-based guideline values for cadmium in residential and commercial/industrial soil.

Jurisdiction	Receptor rotected	Residential	Residential: high density	Commercial or Industrial
Australia	Human health	20	80	100
United Kingdom	Human health	1, 2, 8[a]	30	1400
Canada	Human and ecological health	10	–	22
Netherlands	Human and ecological health	0.8, 12[b]	–	–
MfE CLMG #2 guidelines	Human health	1.0- 2.0[c]	-	22

[a]Figures for sandy soils at pH values of 6, 7, and 8, respectively.

[b]Target value and intervention value, respectively.

[c]Sandy soils of pH 6 and pH 7, respectively.

For example, a value of 1 mg/kg for acidic soils has been employed as an initial screening level by some councils for residential subdivisions undergoing residential development based on MfE's CLMG #2.

This situation may change in the future, depending on progress with the development of New Zealand guidelines or standards for cadmium in residential and/or agricultural soils.

A question that has not yet been considered at a national level is whether one of the aims of any New Zealand soil guideline or standard for cadmium should be to protect against the likelihood of food standards being exceeded in either home-grown produce, or crops grown for export.

Note on application of guidelines

It is important to note that in relation to individual residential properties, the guideline value selected according to CLMG#2 do not immediately confirm that a site is contaminated, for the following reasons:

In regional soil monitoring programmes, single composite soil samples are usually collected from each property, and each sampling site is merely one survey point in a larger network. In this context, a finding that a small percentage of samples exceed a given guideline is used as a trigger for further investigation. Such investigation may include an assessment of causes, trends, significance, management options, and the applicability of the guideline itself.

By contrast, contaminated site investigations require the detailed examination individual properties. The property-specific requirements of a contaminated site investigation include the assessment of land-use activities that may have caused contamination and their locations, identification of contaminants, a soil (and often groundwater) sampling programme, and quantification of pathways and risks. The requirements of contaminated sites investigations are provided in the Ministry for the Environment's Contaminated Land Management Guidelines series (most specifically CLMG#1, CLMG#2 and CLMG#5).

For these reasons it would not be valid identify an individual property as a 'contaminated site' merely on the basis of the soil sample collected as part of a regional council monitoring programme.

Estimating the extent of land which could be affected

Peri-urban subdivision in New Zealand

The impact of risks to land-use flexibility (for subdivision) depends on the demand for land use change from agricultural production to residential subdivision.

Statistics New Zealand (2001) estimate that the number of households may increase by 380,000 or 26 percent between 2001 and 2021, from 1.44 million to 1.82 million. This translates to an average annual increase over this period of New Zealand of approximately 19,000 households per annum until 2021. A national figure in the vicinity of 20,000 new residential houses per year is confirmed by the number of buildings consents that have been issued. From January to December 2005, approximately 22,000 new building consents were issued for residential dwellings, excluding apartments (and 26,000 with apartments) (Statistics NZ, 2005). The annual area involved is approximately 2000 ha per annum of largely peri-urban land.

However, not all new dwellings will be subdivisions built over former agricultural or peri-urban land. There are distinct differences between regions in the amount of rural land likely to be subdivided in order to meet demand for residential housing. For example, the Auckland

Regional Growth Strategy[9] aims to create proportionately more new high density housing than has occurred in the past - meaning that, if the strategy successfully influences subdivision, there should be less new housing occurring over former agricultural land, and therefore a lesser risk of cadmium becoming an issue for those wishing to subdivide.

In Waikato, evidence points to the vast majority of new housing being built over former agricultural land. Over the next 20 year period, demand for new dwellings in the Wellington region is projected to total 1500-1700 per year; however, in this region, more than half of these are expected to be high-density dwellings (apartments) (Heath & Osbourne, 2005).

Estimating the likelihood of subdivision impacts

It is not possible to quantify the proportion of properties that may be deemed unsuitable for subdivision for suburban or lifestyle block use now or in the future. The main uncertainty in this case is over which of the range of possible residential soil screening values (Table 6.1) will be adopted by given regional or territorial authority in any given case. The lower the guideline value used for assessment, the greater the likelihood of properties being deemed to have unacceptably high soil cadmium levels.

A second consideration is whether a regional or territorial authority will opt to require site assessment and soil remediation prior to granting a subdivision consent. If these actions are not required, then cadmium levels would not be measured and therefore would not influence the subdivision process. However, site assessment has become commonplace for subdivision of former orchard areas due to the presence of pesticide residues, and is becoming increasingly common for other farms: cadmium is usually tested for as part of this screening.

It is important to bear in mind that most subdivisions on former horticultural or agricultural land will occur on the peri-urban fringe. Many horticultural or agricultural properties may never be subject to subdivision (especially those in remote rural areas).

What would the consequences of potential impacts on subdivision be?

In terms of consequences in cases where some form of assessment or remediation is required, financial losses to property owners could be:

- costs of a preliminary site investigation to establish whether guideline values are likely to be met, and (if they are not);
- costs of remediation (usually involving soil mixing or removal);
- costs of a site validation report;
- additional costs associated with a more involved resource consent assessment;
- influence on the market value of a property.

In cases where land is deemed to be contaminated with cadmium as a result of fertiliser use, potential liability consequences also arise for regional councils. This is because the discharge of fertilisers is a Permitted Activity under Regional Plan rules. The success of any such liability claims would depend on whether a council was following established best-practice, and whether or not the adverse effect could have been reasonably foreseen.

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9 For details of implementation of the Auckland Regional Growth Strategy, see: http://www.arc.govt.nz/arc/index.cfm?F4C37855-BCD4-1A24-9FC8-508AC54C08E4

Conclusions on risks to land-use flexibility for subdivision

In New Zealand, a substantial portion of new residential housing development takes place over agricultural (pastoral and horticultural) land. Most broad-acre agricultural land across New Zealand is now slightly elevated in cadmium due to widespread use of phosphate fertilisers.

In the absence of mandatory regulations for managing contaminants, local authorities are encouraged to make use of a selection of best-practice guidelines when dealing with contaminated land issues. At present, it would appear that:

There is a *moderate* probability that some territorial authorities, following best-practice, will deem some agricultural land undergoing subdivision as being unsuitable for residential use without remediation, due to its elevated cadmium content.

There is a *moderate* probability that some regional councils, following best-practice, may adopt a guideline value for cadmium in soil that is subsequently found to have the effect of formally defining wide agricultural areas as 'contaminated land' under the RMA Amendment Act (2005).

Currently there is also an unknown probability that ERMA may set an Environmental Exposure Limit (EEL) for cadmium that could subsequently be adopted by local authorities as an applicable standard for the purposes of the RMA Amendment Act (2005), leading to the same outcome as discussed above.

There is a *high* probability that approaches to managing this issue will start to vary more considerably from place to place, depending on decisions made by local authorities in different areas of New Zealand. Inconsistency between regions in resource consent requirements and management of contaminated sites has previously been identified as a concern by industry groups (i.e. the oil industry and the timber treatment industry). Apart from inconvenience and multiplication of compliance costs, such an approach can lead to considerable local, national and international confusion.

While retaining land-use flexibility for subdivision purposes is certainly desirable, it should be recognised that some loss of land use flexibility often occurs with most land-uses. It may not be realistic to expect that all agricultural or horticultural land could or should be easily converted to residential use.

Many factors influence land-use change and land-use flexibility, including topography, climate, property values and social aspirations. For example, land that is currently in conservation or indigenous forest is unlikely to be subdivided to residential use without substantial protest. Similarly, once land is subdivided, the ability to change land-use back to agricultural use is extremely limited, if not impossible. While current land-use practices should take into account the need to protect future land-use flexibility options, there is a question of balance between this and the importance of minimising impediments to current land use. The need to protect land use flexibility is probably most pertinent to those horticultural properties bordering towns.

Risks to flexibility to change between agricultural land uses

Discussion of potential constraints to changing between agricultural land uses

The main areas where cadmium accumulation in New Zealand soils may limit the ability to change from one agricultural land use to another are outlined below. Primarily, this could occur if land became enriched with cadmium while it was subject to an agricultural use that required ongoing applications of phosphate fertiliser (such as dairy), and then subsequently was used to grow a crop with a higher sensitivity to soil cadmium (e.g. certain leafy vegetables). Cadmium accumulation is likely to pose less of a problem as long as the land was used for producing food items with little or no sensitivity to soil cadmium (forestry, dairy, meat and wool), but the future ability to use the land for a more-sensitive land use would be constrained.

The following sections discuss inter-conversions between agricultural land uses where problems might occur due to the build up of soil cadmium.

Land currently in horticulture

Cadmium accumulation in soils under horticulture has the potential to reduce land use flexibility for both the current land use, and one potential future use.

A horticultural land-use issue might arise where cadmium accumulation has become sufficient to cause food standards to be exceeded in some crops grown on a given property (Roberts *et al*, 1995; Gray *et al*, 2001; Jinadasa *et al*. 1997). This issue may not become evident until there is a shift from one type of crop not subject to significant cadmium uptake (such as fruit) to another that is more responsive to the soil cadmium that has already accumulated (such as leafy vegetables). Such an issue might also remain hidden until testing of the food revealed the existence of significant non-compliances, either in New Zealand or at an export destination.

Loss of soil resource through this mechanism might be quantified in monetary terms as either or both of:

- income loss associated with no longer being able to market a certain crop grown on the property; and,
- costs incurred for any special management approaches required to ensure that cadmium uptake in plants remains within an acceptable upper boundary.

Land currently in pastoral agriculture

Pastoral to horticultural conversion:

Where land is converted from pastoral agriculture to horticulture (e.g. vegetable growing or arable farming) a problem may arise where accumulated cadmium is taken up by the crops at levels to cause food standards to be exceeded. Cadmium that has accumulated in the soils on sheep, beef or dairy farms may be sufficient to cause food standards to be exceeded in some leafy vegetables or grain crops grown on the property, after the land use has changed.

Estimating the amount of land that could be affected

As is the case for residential subdivision, it is not possible to provide a precise estimate of the amount of land that would currently be unsuitable for production of some foods as a result of cadmium accumulation in New Zealand's productive soils. Partly this is caused by limited data being available for cadmium in New Zealand soils, but mainly by differences in soil properties which can lead to variable amounts of cadmium uptake for the same crops grown from different soils (see Chapter 4).

A current reality is that whether or not New Zealand opts to set a national guideline for soil cadmium, some of the most conservative international guidelines have been passed in some broad-acre soils, and it appears likely that in the absence of specific management progressively more international guidelines will be passed as time goes on.

Conclusions on risks to flexibility to change between agricultural land uses

The working group consider that under current management approaches:

- There is a *moderate* risk that any local authorities may adopt a conservative soil guideline for cadmium (or possibly a standard set by ERMA) as an applicable standard for soil contaminants under the RMA Amendment Act (2005), and subsequently find that large areas of their agricultural land have been thereby defined as being contaminated through operation of the Act.
- If local authorities did opt for a conservative soil guideline for cadmium, there would be a *high* risk that cadmium accumulation will be sufficient to require remediation of land prior to subdivision consent being granted.
- There is a *high* probability that under the current approach of leaving most decisions to local authorities, management of the issue will vary widely across different districts and regions of New Zealand, leading to unnecessary compliance costs through duplication, and confusion over how well the issue is being managed.

Cadmium accumulation in soils is one primary cause of these risks. However, these risks are also developing (or are exacerbated) through absence of an integrated national policy for the management of soil contaminants. Absence of such a policy increases the probability that some local authorities will select the most conservative soil guidelines to minimise liability, leaves the possibility open that one or more local authorities may at any time adopt a soil guideline for cadmium that inadvertently defines large agricultural areas as 'contaminated land', and is the primary reason for differences in approach across New Zealand.

Chapter summary

There are two main adverse impacts on land use flexibility which could occur from cadmium accumulation:

1. Cadmium accumulation in agricultural soils could affect the future ability to subdivide the land for residential or rural-residential purposes without some form of rehabilitation. In New Zealand, a substantial portion of new residential housing development takes place over agricultural (pastoral and horticultural) land, which is often moderately elevated in cadmium due to use of phosphate fertilisers. While such land is unlikely to pose any human health risks, it may exceed a guideline value for acceptable cadmium levels in soils, depending on the guideline value selected depending on the land use.

   This problem would mostly affect those with land that had received ongoing applications of phosphate fertiliser (e.g. dairy), that was close to the perimeter of an urban area and who wished to subdivide their land into residential blocks.

2. If cadmium in agricultural soils built up to significant levels over time, this could affect the ability of landholders to grow certain types of agricultural products, due to the cadmium levels in these products exceeding food standards, or best-practice requirements set by overseas markets (such as EUREP-GAP).

   This problem could affect people wishing to convert from a land use which had required ongoing phosphate fertiliser application (e.g. dairy or pastoral) to growing a horticultural crop which was sensitive to cadmium levels in the soil. It could also affect those wishing to switch from growing fruit crops to certain leafy vegetables, if the land had received significant phosphate application whilst growing fruit.

The two different land-use flexibility issues require different responses. The first type of risk stems from some uncertainty over how regional councils should best assess and approach the issue of cadmium, and other contaminants, in soils. It could be addressed through the development of a National Environmental Standard.

The second type of risk needs to be managed through improved monitoring of cadmium levels, providing information to farmers and growers, ensuring that the standards used to assess safe levels of cadmium in food are interpreted and applied in a consistent and science-based manner, and, where appropriate, on-farm management techniques such as deep-ploughing or liming to manage cadmium levels in soils.

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Chapter 7: Conclusions and recommendations

Cadmium accumulation in soils increases the likelihood that some food products grown will also have elevated cadmium concentrations. At a sufficiently high concentration in food cadmium can have implications for human health, market access and trade, and the ability to change from one land use to another. The Cadmium Working Group has found that, in a general sense, these risks from cadmium are not acute. However, as phosphate fertiliser use is likely to continue, or increase, in future, current trends point to ongoing cadmium accumulation in New Zealand soils. This means the issue needs to be actively managed, and a strategy developed to mitigate and manage these risks along the lines of the Australian Cadmium Management strategy.

The areas of risks investigated in this report all stem from a primary concern over human health - that is, the economic impacts of losing agricultural markets due to high cadmium levels, or constraints on land-use flexibility due to breaching soil guideline values are both issues that stem from regulatory systems designed to protect human health. There is a need to not only monitor and manage the levels of cadmium in soil, but also to ensure that the domestic and international regulatory system protecting human health through food standards or land use policies and plans are appropriate, and applied according to consistent and logical methods.

Summary of findings

Risks to human health

The 2003/04 New Zealand Total Diet Survey provides a sound basis on which to conclude that the health risk posed to the New Zealand population from dietary cadmium is very small to negligible. The estimated weekly intake of all age-sex groups surveyed was well below the Provisional Tolerable Weekly Intake as set by the World Health Organisation. Cadmium levels found in the food products surveyed were generally consistent with internationally documented levels (WHO, 1992a; Jensen, 1992).

As most non-smokers' main exposure to cadmium is through food, and since the level of exposure to cadmium through food in the average New Zealand diet is highly unlikely to cause health impacts, it can be concluded that cadmium levels in New Zealand soils currently do not pose a risk to human health in New Zealand, nor are they likely to in the foreseeable future.

Risks to trade and the economy

If cadmium accumulated in soils to levels at which food produced on those soils began to breach food safety standards, both domestic and export sales of these food products would be compromised.

However, large sectors of the agricultural industry are unlikely to breach food safety standards even if cadmium levels in soils were to become significantly elevated. This is generally because many food products are not the same part of a plant or animal that stores cadmium (i.e. animals store cadmium in their liver and kidneys, therefore milk and muscle meat always have low cadmium concentrations). Agricultural products that are sensitive to soil cadmium levels are vegetables and offals, although cadmium levels in offals can easily be managed through the discard process (i.e. by discarding offals from animals over a particular age at which cadmium levels start to become significant). Any future elevation in soil cadmium levels would most likely affect sections of the vegetable industry.

Even though the short-medium term risk to New Zealand's economy is low, cadmium is likely to accumulate in soils with the continued use of phosphate fertilisers. Therefore it is important to consider ways to mitigate future risks to the agricultural sector (particularly the leafy and root vegetable industry). These risks could occur either directly from food standard exceedences in particular crops, or indirectly through damage to New Zealand agriculture's international reputation as clean, green and safe.

Risks to land-use flexibility

Accumulation of some persistent trace contaminants in soils has the potential to reduce land use flexibility over time. There are essentially two ways in which this problem could arise. The first type of risk could affect people wishing to subdivide agricultural properties into residential properties, and depends largely on the way in which each of New Zealand's regional councils choose to assess the acceptability of heavy metals in soils. The second type of risk to land-use flexibility is that soil cadmium may accumulate to a level at which it is no longer possible to change from one agriculture land use to another, because the soil is not suitable for growing crops that are more sensitive to cadmium.

In the first case, land-use flexibility would be reduced is when a landowner applies for a resource consent to subdivide an agricultural property to another land use. As part of the subdivision process, regional councils will undertake routine soil testing for contaminants. Remediation (which can be difficult and expensive) will be required if the soil is deemed to have unacceptably high cadmium levels.

The other instance in which a loss of land-use flexibility could occur is where crops from a particular property showed frequent exceedences of cadmium food standards and this was picked up by random testing and traced back to the farm (with the consequence that sales from that property would be affected). This would most likely occur if land which had received significant phosphate fertiliser applications under a pastoral agricultural system was subsequently used to grow horticultural products (in particular some varieties of vegetables), which are sensitive to cadmium levels in soils. Therefore, this form of loss of land-use flexibility would most likely affect people wishing to convert from dairy or pastoral to horticultural land use, or from growing fruit crops to vegetables.

Regional councils rely on guidance from the Ministry for the Environment to help them select a measure to indicate whether soil cadmium levels are such that further investigation or remediation is needed. There are a number of guidelines or measures developed in New Zealand, which are available for regional councils to use in their assessment of soil cadmium levels. These guidelines highlight what levels of cadmium are deemed acceptable for different forms of land use.

The two different land-use flexibility issues require different responses. The first type of risk stems from some regulatory confusion over how regional councils should best assess and approach the issue of cadmium, and other contaminants, in soils. It could be addressed through the development of a National Environmental Standard.

The second type of risk needs to be managed through improved monitoring of cadmium levels, providing information to farmers and growers, ensuring that the standards used to assess safe levels of cadmium in food are interpreted and applied in a consistent and science-based manner, and, where appropriate, on-farm management techniques such as deep-ploughing or liming to manage cadmium levels in soils.

Conclusions and recommendations

An emerging issue and a need for strategic management

Overall, cadmium accumulation in soils does not pose an immediate or severe risk to New Zealand agriculture and food safety in the immediate future. There may be risks to land-use flexibility in some regions.

However, cadmium accumulation in agricultural soils can be characterised as an emerging issue, which therefore needs strategic management to prevent it from becoming a more serious and acute problem in the future. Given that current economics are driving a trend towards agricultural intensification, particularly towards dairy, it is reasonable to assume that the use of increased rates of phosphate fertilisers will continue. Unless a cost effective process for removing cadmium from phosphate rock is developed, this is likely to lead to continuing accumulation of cadmium in agricultural soils, raising the risk of breaches of food safety standards in food crops grown on those soils and in animal offal. Similarly, the demand for housing and urban expansion means that residential subdivisions are likely to continue to expand over former agricultural lands, creating the potential for soil cadmium to emerge as an impediment to subdivision.

Cadmium accumulation is an ongoing issue that is not going to go away. It is prudent to develop a strategy to managing the risks before they occur.

The Cadmium Working Group recommends that:

- Cadmium accumulation in agricultural soils be recognised as an emerging issue, with local and central government committing to giving it ongoing attention.
- A national cadmium strategy should be developed supported by all stakeholders in order to mitigate future risks from cadmium.

Clarifying New Zealand's policy approach towards cumulative contaminants

The questions surrounding the appropriate management of cadmium accumulation raise a wider issue regarding the general policy approach that New Zealand should take towards cumulative contaminants in agricultural soils. At a national level New Zealand has not adopted an explicit policy position on the preferred approach to dealing with potentially cumulative contaminants in agricultural soils to ensure long-term sustainability. Two models are a mass-balance approach that aspires to no net accumulation (after a certain period), and a risk based approach, where accumulation is permitted until a set limit based on a risk assessment is reached. As various organisations have roles for different aspects of cadmium e.g. soils levels, food safety, the functions for the different parties that have a regulatory role in addressing contaminants such as cadmium also needs to be clearly identified.

The Cadmium Working Group recommends that:

- Policy direction be provided as to the preferred New Zealand model for managing risks to sustainability posed by cumulative heavy metal contaminants in agricultural soils: either the mass balance or risk-based (which usually permits some accumulation up to a set threshold or investigation trigger level).

Managing risks to economy and trade

In the short term the risk to the New Zealand economy is *low.* Any risks from significant accumulation of cadmium fall in a relatively small segment of the agriculture sector; mainly leafy vegetable producers and offal from animals. Dairy (milk), muscle meat and fruit products are unlikely to be at risk on the basis of cadmium levels, due to the low capacity of these products to store cadmium. The New Zealand Food Safety Authority currently has a process in place that manages the risk posed by offal's containing high levels of cadmium.

Although the Cadmium Working Group's preliminary analysis of New Zealand's soil cadmium levels has suggested that concentrations are not approaching a level at which vegetable crops would be compromised, there is a need for a strategic, anticipatory policy approach to ensure that the vegetable sector is not affected in the future.

Any future management strategy for cadmium should pay particular attention to the horticultural sector, and should be developed in consultation with this sector. Such a strategy should include consideration of the situation when land, which has received significant phosphate fertiliser (such as is common for land used for pastoral agriculture and fruit growing), is converted to vegetable growing, and the need for the provision of information, monitoring and remediation which might be needed for such a conversion to take place.

The Cadmium Working Group recommends that:

- The national cadmium strategy is developed with particular attention to, and consultation with, the horticultural sector.
- The meat industry should assess the ongoing suitability of current risk management practices for meat products such as offal's in line with a national cadmium strategy.

Providing clarity for local authorities

Local authorities need guidance as to how to best deal with the issue of cadmium enrichment in former agricultural properties when considering land for subdivision. There is a high probability that under the current approach of leaving most decisions to local authorities, management of the issue will vary across districts and regions of New Zealand, depending on historic or intended land use.

The Cadmium Working Group recommends that:

- The Ministry for the Environment gives greater guidance to local authorities, in order to ensure that cadmium levels are assessed and evaluated in a consistent and appropriate manner. This guidance could be in the form of a National Environmental Standard on the assessment and evaluation of cadmium in soils under a variety of land uses, possibly with a tiered approach in which soil cadmium levels are linked to specific management action(s);

Improving information on New Zealand's soil cadmium levels

A strategic, coordinated approach to managing cadmium requires more systematic data collection on cadmium levels in fertilisers, soils, plants and animal offals in different regions of New Zealand. There is currently a lack of sound, up-to-date information and research to allow more concrete estimation of when and where such risks might develop.

The Cadmium Working Group recommends that:

- A national monitoring programme be established for ongoing fertiliser, soils, plant and animal cadmium levels assessment. This is needed for meeting the regulatory requirements of a number of organisations. This programme should include the following features:

    - Nationally consistent methods and protocols for collection, sampling and analysis of cadmium e.g. soil sample depth and number, in order to allow for comparison of results.
    - Timely updating of monitoring data on cadmium levels, at least every 5 years.
    - Greater co-ordination between organisations in collecting and providing data on cadmium levels locally and nationally.
    - Determine the impact on cadmium levels of farming practices or land uses e.g. zinc use.

Understanding non-compliances with food standards

There is limited reliable information about compliance of New Zealand foods with standards for inorganic contaminants listed in the joint Australian and New Zealand food standards (these are, for various foods, the metals arsenic, cadmium, lead, mercury and tin). Of the contaminant elements, cadmium is the element most likely to occasionally exceed food standards in some vegetables, wheat grain, liver and kidney.

There are some unresolved questions about how food standards should be interpreted for contaminant elements:

- For wheat grain, there is an unresolved ambiguity over whether the food standard applies to wheat grain as harvested, or as eaten in products such as bread.
- For contaminant elements in vegetables, a question exists over whether a small but persistent frequency of non-compliance with food standards is at all tolerable, and if so, what background rate would be tolerated (e.g. 0.1%, 1%, 2%, 5%, 10%).
- For contaminant elements in vegetables and wheat grain, if the tolerable rate of food standard non-compliance is zero, should the preferred approach be to minimize the potential for non-compliance at the farm level, revisit the joint food standards with Australia, or both?

The Cadmium Working Group recommends that:

- The New Zealand Food Safety Authority assess the need to undertake a comprehensive food compliance survey of cadmium in vegetables, wheat grain, liver and kidney, in order to:
    - better determine the population distribution of cadmium each food type, and;
    - more reliably determine the actual rates of persistent non-compliance with food standards.
- New Zealand officials approach Food Standards Australia and New Zealand for a discussion on:
    - Appropriate interpretation of the joint food standard for cadmium in wheat; and
    - What, if any; ‘background rate’ of non-compliance in vegetables would be regarded as tolerable; and

- Prospects for fine-tuning the Australian and New Zealand food standards to accommodate special features of the population distribution of cadmium in selected foods.

Next steps

The Cadmium Working Group believes that a further report needs to be developed that will investigate and assess a range of possible options to control the build up of cadmium in New Zealand. Based on the issues raised in this report, the options in the next report should focus on exploring:

1. The role of national standards and/or guidelines for soil cadmium levels, including the intersection of the cadmium issue with Ministry for the Environment’s work on National Environmental Standards and the usefulness of a national policy or standard for soil cadmium;
2. The standardisation of sampling and analytical procedures, protocols and methodology for cadmium;
3. Where current management activities can be strengthened or directed towards the strategic risks and information gaps identified in this report. For example; whether the New Zealand Food Standard Authority should study produce from home gardens; whether regional council soil monitoring can focus more attention on cadmium; whether consideration be given to differentiating between total and bio-available cadmium;
4. The potential economic costs associated with reducing cadmium inputs to soil, and whether they outweigh the benefits of mitigating the risks;
5. Opportunities for increased investment in technology to remove cadmium from phosphate rock;
6. Farmer education on cadmium issues, including whether existing fertiliser codes of practice should include more guidance on cadmium;
7. Identification of on-farm management practices to mitigate risks to horticulture and agriculture: for example, deep ploughing, liming or selection of crop varieties with low cadmium uptake; and
8. The indicative content of a National Cadmium Management Strategy.