Managing cadmium in food crops in New Zealand

This practical guide was developed by the Cadmium Management Group to provide growers with advice about managing cadmium in New Zealand agriculture, including why it needs to be managed.

What is cadmium?

Cadmium is a widespread, naturally occurring element that is present in low concentrations in soils, rocks, plants and animals. It is not essential for life and in high concentrations can be toxic. Cadmium is absorbed by plant roots and transported to different parts of the plant, and in this way can enter the food chain.

Why can it be an issue?

Cadmium can accumulate in some human and livestock organs, particularly the liver and kidneys, mainly through the consumption of food. Excessive daily intake of cadmium over the long term can lead to health problems in humans and animals. In humans, excessive cadmium increases the risk of kidney and bone disease[1], while in livestock, reproduction and the ability to metabolise copper can be reduced[2]. It is therefore important to produce foods in ways that minimise cadmium uptake in order to protect human and livestock health.

New Zealand, through Food Standards Australia New Zealand (FSANZ), has set maximum levels (MLs) for cadmium in food products for human consumption. Where an ML for cadmium is exceeded, those food products may not legally be sold and the Ministry for Primary Industries will take action to alert the supplier.

Current dietary surveys of New Zealanders indicate that the typical daily intake of cadmium is well below the World Health Organization tolerable monthly intake guidelines, so it is unlikely that at current cadmium levels in food there are adverse health implications for New Zealanders. However, surveys in New Zealand have shown that the amounts of cadmium in some foods have occasionally approached or marginally exceeded these regulatory limits, highlighting the need for vigilance by growers to ensure compliance is maintained.

Non-compliance with MLs in exported food products could result in rejected shipments and may negatively affect the international reputation of New Zealand food products.

What are the sources of cadmium?

New Zealand soils contain little cadmium naturally, ranging from less than 0.1 to 0.6 mg/kg soil. Phosphate fertilisers contain cadmium as an impurity in phosphate rock and are the primary input of cadmium to agricultural soils. The fertiliser industry has had a voluntary limit for cadmium levels in phosphate fertilisers of 280 mg cadmium/kg of phosphorus in place since 1997. Superphosphate is now manufactured using lower-cadmium sources of phosphate rock than before 1997, but the amount of cadmium in a fertiliser product still depends on the source of

[1] World Health Organisation 2019. Exposure to cadmium: A major public health concern. www.who.int/ipcs/assessment/public_health/cadmium

[2] Lane EA et al. 2015. Cadmium exposure and consequence for the health and productivity of farmed ruminants. Research in Veterinary Science 101: 132–139. doi.org/10.1016/j.rvsc.2015.06.004

phosphate rock. The average phosphate fertiliser cadmium concentration between 2003 and 2020 was 177 mg/kg of phosphorus[3].

Composts and manures may also contain cadmium (typically <1 mg/kg product). While they generally contribute less cadmium to soils than phosphate fertiliser, management of cadmium should still be considered when using these products. Rain and irrigation water typically have very low amounts, and in agricultural regions the amounts added to the soil from the atmosphere are minimal.

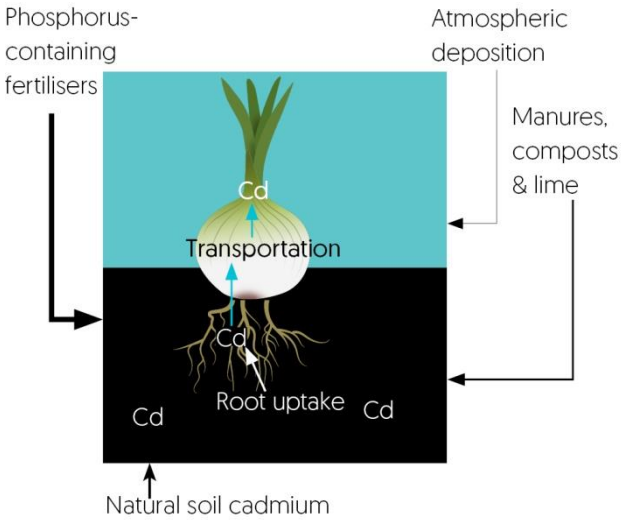
How do plants take up cadmium?

Plants absorb most of their cadmium from soil through their roots, where it can move to the leaves, grains and fleshy fruit. Typically, cadmium accumulates more in the leaves than in roots and grains, with fleshy fruit accumulating the least.

Cadmium added to soil is strongly bound to minerals and organic matter and therefore tends to remain in the topsoil, where it is potentially available to plants. The availability of cadmium to plants is influenced by a number of factors, but in general more cadmium is available as soil pH decreases (becomes more acid). Amounts of soil micro-nutrients, in particular zinc, also affect cadmium uptake by plants, with more cadmium being taken up if soils are low in zinc.

Uptake can vary considerably among different plant species, and among different varieties or cultivars of the same species. However, the variation in cadmium concentrations in the edible produce of a single cultivar at different locations may be as great as the variation between different cultivars at a single location, emphasising the importance of understanding the influence of both soil and plant factors on cadmium accumulation in plants.

Potential sources of cadmium and uptake by plants



[3] www.fertiliser.org.nz/Site/about/fertiliser_use_in_nz, accessed June 2020.

How is cadmium managed in New Zealand?

A National Cadmium Management Strategy sets out the approach to managing cadmium in the primary sector. Implementation of the Strategy is overseen by the Cadmium Management Group, which includes representatives from the Ministry for Primary Industries (including New Zealand Food Safety), the Ministry for the Environment, Foundation for Arable Research, Horticulture New Zealand, the fertiliser industry (including the Fertiliser Association of New Zealand), Potatoes New Zealand, Federated Farmers, Beef+Lamb New Zealand, DairyNZ and regional councils, with Manaaki Whenua – Landcare Research providing technical support as an observer.

The Cadmium Management Strategy has the objective:

> ***To ensure that cadmium in rural production poses minimal risks to health, trade, land-use flexibility and the environment over the next 100 years.***

Actions to achieve this include:

- monitoring to ensure the risks are being managed appropriately, and to contribute to the knowledge base of where and how risks from cadmium arise
- controlling the accumulation of cadmium in soils and the management of priority products to protect against non-compliance with food standards
- research on ways to manage cadmium risks
- communications to raise awareness of cadmium as an issue and to promote the use of risk management tools.

Food monitoring

The dietary intake of cadmium among New Zealanders is monitored through the New Zealand Total Diet Study. The study is undertaken by New Zealand Food Safety approximately every 5 years. Samples are taken from products sold in supermarkets and other retail outlets that are representative of foods in the New Zealand diet.

Other surveys of food residues may also include data on cadmium, including periodic specific priority product surveys. Current priority products from a dietary perspective are wheat, spinach, potatoes and onions and, from an export perspective, potatoes, onions and offal for human consumption.

Soil and fertiliser cadmium monitoring

Soil monitoring is undertaken through testing for cadmium alongside routine nutrient analysis in agricultural soils. Regional councils also test for cadmium in soils across a range of landscapes for State of the Environment reporting. Fertiliser companies regularly test cadmium levels in their phosphate fertiliser products, which is audited through the Fertmark quality assurance programme run by the Fertiliser Quality Council.

The accumulation of soil cadmium in agricultural land can be managed using the Tiered Fertiliser Management System, which sets out increasingly stringent restrictions on the choice and rate of phosphate fertiliser as soil cadmium increases. The soil cadmium tiers represent amounts of soil cadmium ranging from

natural background (Tier 0, <0.6 mg Cd/kg soil) up to an agreed maximum threshold of 1.8 mg/kg soil (Tier 4). The Tiered Fertiliser Management System is available on the Fertiliser Association of NZ website (http://www.fertiliser.org.nz/Site/resources/tools).

However, non-compliance with food standards can occur for some products even when grown in low-cadmium soils. For example, surveys across commercial food crop-growing regions showed that most soils were within Tier 0 of the Tiered Fertiliser Management System, but cadmium levels in some edible products were near or just above the relevant ML. This highlights the importance of the monitoring and agronomic management considerations outlined in this pamphlet.

Cadmium in New Zealand food and exports

The 2016 Total Diet Study found that the typical diet of New Zealanders is well within the World Health Organization's recommended limits for cadmium intake, and also within the range reported in international dietary surveys. It also found no evidence of an increase in cadmium exposure through diet, and no consequent increase in dietary risk. Finally, the study also identified that concentrations of cadmium in ground crops, such as carrots and onions, and in grain-based foods, have remained unchanged over the past 30 years[4].

Nationally and internationally MLs for cadmium in food products are set to protect public health, and to be reasonably achievable from the perspectives of sound primary industry production and natural resource management. These MLs can vary among countries. Domestic products must comply with MLs set by Food Standards Australia New Zealand (FSANZ), which are 0.1 mg/kg fresh weight for wheat, leafy greens, and root and tuber vegetables. Exported produce will also need to comply with the importing countries' MLs. A large proportion of onions are exported and importing countries commonly use the MLs set by the European Commission (EC 1881/2006) or Codex 193-1995, which are 0.05 mg/kg fresh weight.

The relationship between soil cadmium and plant cadmium is complex. Recent surveys of cadmium in a single potato cultivar across key New Zealand commercial growing regions have revealed that cadmium concentrations in peeled tubers were generally well below the FSANZ ML, and there was no obvious regional difference in tuber concentrations despite marked differences in amounts of soil cadmium. Across key commercial growing regions, the amounts of cadmium in onions were below the EC and Codex MLs of 0.05 mg/kg fresh weight, and different varieties of lettuce were generally markedly below the FSANZ ML for leafy greens of 0.1 mg/kg fresh weight. Cadmium concentrations in baby leaf and bunching spinach were higher, with the occasional mild exceedance of the FSANZ ML for leafy greens of 0.1 mg/kg fresh weight. Finally, despite the low amounts of soil cadmium in Canterbury, the predominant bread and biscuit wheat-growing region in New Zealand, cadmium in whole wheat grain can be near, or occasionally mildly exceed, the FSANZ ML for wheat of 0.1 mg/kg fresh weight.

How can I tell if I have a cadmium issue?

- Regularly monitor your edible produce (crop) for cadmium, including different crops/varieties.
- Know your soil cadmium levels.
- Know your soil properties (pH, organic matter, zinc and Olsen P), which will provide valuable information for managing cadmium accumulation.

Non-compliance with food standards typically occurs at concentrations lower than those that will negatively affect yield or plant health. Therefore, monitoring your edible produce is required to determine whether you have a potential cadmium issue. Understanding the variation in uptake by different crops/varieties and knowing your soil properties will help to identify when there is a higher risk of having a cadmium issue.

How can I manage for low cadmium in food crops?

Reducing cadmium inputs – don't over-fertilise!

Phosphate fertilisers are the primary source of cadmium in agricultural soils, so reducing their application rate and/or switching to lower cadmium-containing fertilisers (e.g. phosphoric-acid- or nitric-acid-derived fertilisers) will reduce the input of cadmium to soils. Olsen P is a key indicator of phosphate fertiliser requirements and phosphorus fertiliser can be reduced where Olsen P is at the recommended levels for your crop and soil type. Advice on the appropriate fertiliser rate can be obtained by soil testing, from your soils and fertility advisor, and by using nutrient references guides or nutrient management models. Also see the Vegetables Research and Innovation and the Fertiliser Association resources pages for more information (www.vri.org.nz/research/, www.fertiliser.org.nz/Site/resources/booklets).

Where appropriate, phosphate fertiliser can be applied in bands to improve phosphorus availability and reduce the overall soil loading rates.

[4] www.mpi.govt.nz/food-safety/food-monitoring-and-surveillance/new-zealand-total-diet-study

Phosphoric-acid-derived fertilisers (e.g. triple superphosphate, DAP) typically have lower cadmium concentrations than sulphuric-acid-derived products (e.g. superphosphate) and rock phosphate. Nitric-acid-derived fertilisers (e.g. complex products, with NPK in each prill) generally have the lowest cadmium concentration.

Composts and lime may also be sources of cadmium in agricultural soils, so you will need to ensure that products containing low levels of cadmium are used.

Crop and cultivar selection

Uptake of cadmium varies among different plant species, and among different varieties or cultivars of the same species. Some crops accumulate greater amounts of cadmium. Spinach, silverbeet, carrots, celery, leeks, and wheat generally accumulate more cadmium than onions or potatoes. This means that some stages in a crop rotation cycle are more at risk of non-compliance with food standards.

Different varieties or cultivars can accumulate cadmium at different rates. Testing in New Zealand of a range of wheat cultivars in industry trials identified some typically higher-accumulating cultivars: those derived from the Monad variety tend towards higher cadmium accumulation. Testing of a range of potato cultivars also showed higher- and lower-cadmium-accumulating cultivars.

Improving soil conditions

In general, plant uptake of cadmium can be reduced by:

- increasing soil pH to the high end of the optimal range for your specific crop (often this is around pH 6.2)
- increasing soil organic matter (if applying compost and manures, ensure low-cadmium products are used)
- addressing any zinc deficiency (international studies have shown this to be important) – zinc status is best measured in plant material.

New Zealand-specific research identified a decrease in cadmium concentration in onions as soil pH increased, suggesting that maintaining pH at the maximum optimal pH will help to reduce cadmium accumulation. For bunching spinach there was a decrease in cadmium concentration with increasing organic matter, suggesting compost addition may help to reduce cadmium accumulation in this crop. In contrast, there were no identified relationships with soil properties and cadmium concentrations for wheat or potatoes, placing greater emphasis on knowing the variation in cadmium uptake among different cultivars.

However, for wheat there is a strong relationship between the zinc:cadmium ratio and cadmium concentrations in grain (see figure), suggesting that zinc addition (to soil, or foliar application) could help to reduce cadmium accumulation in some cases.

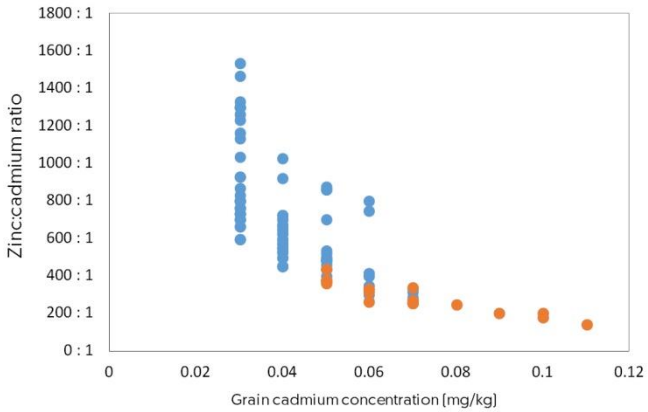


Figure: General trend of increasing grain cadmium concentration with decreasing zinc:cadmium ratio for 22 bread and biscuit wheat cultivars grown at 10 sites in Canterbury. The orange dots show the concentrations in 17 cultivars grown at one site. The spread of all dots combined reflects the importance of both location and cultivar in determining grain cadmium concentrations.

Cadmium is generally more available to plants grown in soils with a low clay content. Therefore, the risk of high cadmium levels in produce is generally greater for sandy soils in comparison with clay soils. Plant uptake of cadmium is also generally lower in Granular and Allophanic (volcanic) soils than in non-volcanic soils.

Next steps

You've read this guide. What now? The Cadmium Management Group encourages you to consider how to include the management of cadmium in your farm or orchard management plan. As first steps, talk with your soils and fertility advisor about including cadmium in your next soil test and the Tiered Fertiliser Management System, and talk to your sector group about monitoring the crops and cultivars you are growing. To find out more about managing cadmium, check out the links below.

Additional resources

www.mpi.govt.nz (search cadmium)
www.fertiliser.org.nz (search cadmium)
www.VRI.org.nz (search cadmium)
www.potatoesnz.co.nz
www.onionsnz.com
www.freshvegetables.co.nz
www.far.org.nz
For more information, contact your sector group.

This guide is one in a series of guides and sector fact sheets produced by Manaaki Whenua – Landcare Research for the Cadmium Management Group in 2020.

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