Fertiliser Association

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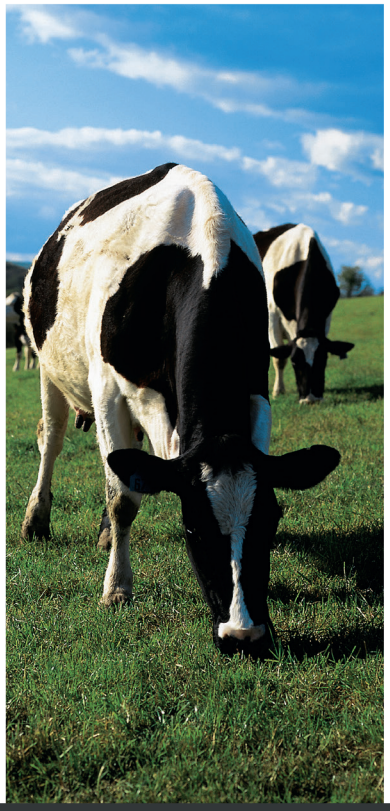


Tiered Fertiliser Management System for Soil Cadmium

For the management of soil cadmium accumulation from phosphate fertiliser applications

Developed by the Fertiliser Association of New Zealand as part of the work programme undertaken as a member of the Cadmium Management Group, which was established by the Regional Councils' Chief Executives' Environment Forum.

Tiered Fertiliser Management System for Soil Cadmium

The Tiered Fertiliser Management System (TFMS) is a component of the New Zealand Cadmium Management Strategy. It has been endorsed by the members of the Cadmium Management Group[1] as an appropriate process for managing soil cadmium accumulation.

The Tiered Fertiliser Management System has the principle purpose of:

- managing phosphate fertiliser applications to control the accumulation of cadmium in agricultural soils.

For a farmer or grower the following actions are especially important.

- Testing soil cadmium levels. This is critical to implementing the TFMS.
- The choice and rate of phosphate fertiliser application—refer to Figure 1.

Background

Although cadmium occurs naturally in soil, the sustained application of phosphate fertilisers and/or bio-solids can lead to an increase in soil cadmium, with implications for uptake by plants.

Plants take up trace levels of cadmium from the soil, which means it can enter the human food chain. Safe levels of cadmium in the diet, over a lifetime's intake, are provided by the World Health Organisation's (WHO) Provisional Tolerable Monthly Intake (PTMI) value, which is 25µg/kg of body weight. The New Zealand Total Diet Survey conducted approximately every five years shows that cadmium levels in a typical New Zealand diet remain well below the recommended WHO level. Occasional mild exceedance of a food standard does not present a health risk, but it can present a market risk for a particular food product, if the food standard is not complied with.

Different sources of phosphate rock contain different concentrations of cadmium and currently there is no viable mechanism to remove cadmium entirely. The fertiliser industry has made a commitment to minimise the cadmium concentration in phosphate fertilisers as much as is practically possible.

Phosphate fertilisers remain an essential requirement for maximising agricultural production. The long-term aspiration is to control cadmium levels so that there is no net accumulation in soil. It is therefore necessary to manage phosphate fertiliser use so that excessive soil cadmium accumulation is avoided.

The Tiered Fertiliser Management System

The Tiered Fertiliser Management System (TFMS) is a system for controlling the choice and rate of phosphate fertiliser application depending on the soil cadmium concentration.

The tiers represent soil cadmium levels ranging from natural background levels up to an agreed maximum threshold. Above this there should be no further accumulation of cadmium unless there is a detailed site-specific investigation to identify risks and pathways for potential harm.

The objective of the TFMS is that soil cadmium accumulation rates are managed so that soil cadmium remains below the upper limit (of 1.8 mg Cd/kg soil) over at least the next 100 years. It achieves this by managing rates of soil accumulation, which are reduced as soil cadmium increases. Regardless of soil cadmium level, plant uptake should be managed appropriately to limit plant and animal cadmium levels to recognised standards.

This TFMS is an integral part of the Cadmium Management Strategy and is currently a voluntary system. It was revised in 2019 following a review of the Cadmium Management Strategy[2].

The Cadmium Management Strategy is implemented by the Cadmium Management Group comprising:

- Ministry for the Environment
- Ministry for Primary Industries
- Regional Councils
- Primary sector representative bodies
- The fertiliser industry.

Management practices to reduce cadmium loading at any soil cadmium level

Box 1: Management practices to reduce cadmium loading

1. Measure soil cadmium levels at a frequency outlined in Appendix 1 (using accredited sampling procedure and an accredited laboratory). This value informs the choice of phosphate fertiliser and its application rate to use.
2. Use fertiliser products with less cadmium per kg phosphorus.
3. Manage phosphate fertilisers to economic optimum soil levels, based on soil phosphorus test results.
4. Seek professional advice for fertiliser recommendations.
5. Phosphate fertiliser applications should be banded (and not broadcast) where possible.

Underlying principles of soil cadmium tiers

The TFMS has five cadmium level tiers, with Tier 0 representing soil cadmium that lies within the range of natural background levels. Tier 4 represents a soil cadmium level where there should be no further cadmium accumulation, unless there is a detailed site-specific investigation undertaken to identify risks and pathways for potential harm.

The Tier 1 soil 'trigger' value (0.6 mg Cd/kg soil): was selected as the 99th percentile of the background soil concentrations described in the Cadmium Working Group report, August 2008.[3]

Table 1: Background Soil Cadmium Levels[3]

Land use	Number of samples	Average Cd (µg g^{-1})	Range (µg g^{-1})
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" Control sites	223	0.19	0.02 – 0.77
Background (excluding "unfertilised" control site) *	152	0.11	0.00 – 0.65
Total Background	**372**	0.16	0.00 – 0.77

* Total Background estimates included sites described as "unfertilised control sites" which dominate the data set. It was not possible to be certain there had been no fertiliser application from drift or contamination of "unfertilised control sites", so results are also provided where these controls sites are excluded.

Soil cadmium levels below the Tier 1 soil trigger value of 0.6 mg Cd/kg soil are considered to rest within the range of natural background levels.

Above the soil value of 0.6 mg Cd/kg, more active management of soil cadmium loading from phosphate fertilisers is introduced.

The soil 'trigger' values for Tiers 1, 2, 3 and 4: are 0.6, 1.0, 1.4 and 1.8 mg Cd/ kg soil, respectively, were selected as key cadmium management values. These were determined by an extensive review of international soil guideline values, which apply risk-based approaches compatible with New Zealand practices, and by expert advice from an international reviewer with expertise in this field.[4]

The TFMS was first implemented in 2011, reviewed in 2018 and revised in 2019. Following the recommendations of the 2018 review of the Cadmium Management Strategy, additional stepped reductions in phosphate recommendations have been introduced at Tier 2 and above. This further constrains the application of phosphate fertiliser and extends the period of time to reach the upper soil cadmium threshold.

Application of the Tiered Soil Guideline Values

Managing soil cadmium accumulation requires:

- soil monitoring
- management of rates and choice of phosphate fertilisers.

Soil monitoring

Knowing the soil cadmium status of paddocks on a farm is required and this is obtained through soil monitoring. Farmers and growers are required to undertake cadmium soil tests using the sample collection procedures in Appendix 1. This will most often be done in conjunction with their fertiliser adviser or rural professional.

- An initial screening of soil cadmium levels can be undertaken with samples taken to 7.5 cm for uncultivated land situations and 15.0 cm for cultivated land, the normal depths for soil nutrient testing.
- As part of monitoring, farmers will be provided with information on the importance of managing cadmium in agricultural soils.

Management of rate and choice of phosphate fertiliser

The TFMS tiers provide a mechanism for controlling soil cadmium levels through the rate and choice of phosphate fertilisers applied.

The tiers create a system, which sets different soil cadmium accumulation rates at each of the tier levels. It reduces cadmium accumulation rates as soil cadmium increases. This approach is conservative in that it assumes all cadmium remains in the surface soil within a depth of 15 cm, with no soil system losses. It also assumes the cadmium levels in the phosphate fertiliser are always at the maximum allowable limit of 280mg Cd/kg phosphate, when in fact fertiliser cadmium levels are kept below this level, to ensure it is not exceeded. See Box 2.

BOX 2: Application of Tiered Fertiliser Management System

Tier 0 Within background levels

- If the soil cadmium screening test results in a soil level of < 0.6 mg Cd/kg soil, this rests within the range of background levels (where no phosphate fertiliser has been added).
- A wide range of options for fertiliser product and rates apply.
- Appropriate management options are recommended. (Boxes 1 and 2)
- A repeat soil cadmium sampling in 5 years is recommended.

Tiers 1 to 3

- For paddocks or farms with a soil cadmium value of ≥ 0.6 mg Cd/kg soil, a further soil cadmium test needs to be undertaken using the sample collection procedures in Appendix 1. If the soil cadmium level is approaching a higher Tier level, repeat sampling may be warranted.
- The choice of fertiliser product and rates are restricted to those which follow Tier 1 to Tier 3 recommendations presented in Figure 1 and Table 2, with increased restriction on phosphate fertiliser choice and application rates as soil cadmium levels increases.
- A conservative approach is advised, with referral to an appropriate consultant when agricultural soil monitoring indicates soils are at Tier 2 soil cadmium values or above.

Tier 4 No net accumulation

- At or above Tier 4, (1.8 mg Cd/kg soil), there should be no net accumulation of cadmium in soil for agricultural production, unless there is a detailed site-specific investigation to identify risks.
- The Tier 4 soil management "trigger" value (1.8 mg Cd/kg soil), represents:

  "a balance between the need to protect human and environmental health for the long-term and the desire to not unnecessarily impact on farmer livelihoods until there is certainty that the limits are the most appropriate for New Zealand soil ecosystems and humans"[4].
- Steps that can be taken to provide for no net accumulation above 1.8 mg Cd /kg soil include withholding P fertiliser, use of special very low cadmium fertiliser, changing land use and /or ploughing to a depth of at least 30 cm, followed by further soil testing using the sampling and testing procedures in Appendix 1.

Farmers should always consider their soil cadmium loading levels.

Deciding on rate and choice of fertiliser

The reference chart (Figure 1) specifies the maximum phosphorus application at each tier level.

Figure 1 shows soil cadmium levels on the vertical axis and phosphorus requirements on the horizontal axis. Colour coded fields for the matrix identify appropriate options for the choice of fertiliser.

Figure1 in combination with Table 2 shows the phosphate fertiliser product groups which can be selected as appropriate for each phosphorus application rate and soil cadmium level.

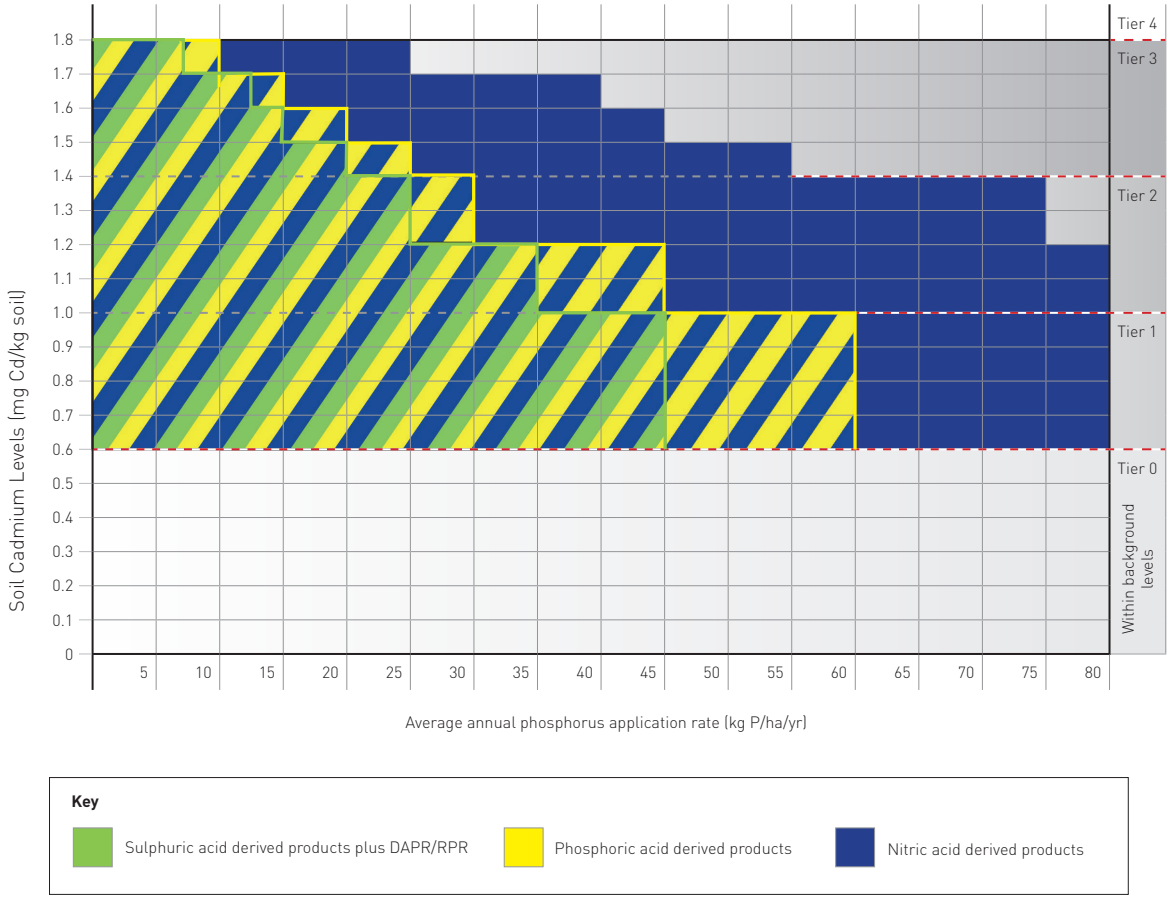
Example

With a soil cadmium level of 1.2 mg Cd/kg soil, and an agronomic phosphorus requirement of **35** kg P/ha/yr, the choice of product is restricted to nitric acid derived products, or a product certified to have a cadmium level comparable to nitric acid derived products, defined as, not greater than 100 mg Cd/kg P or

With a soil cadmium level of 1.2 mg Cd/kg soil, and an agronomic phosphorus requirement of **20** kg P/ha/yr, the choice of product can be any of the nitric acid derived products, phosphoric acid derived products or sulphuric acid derived products, or a product certified to be comparable to these, defined as cadmium levels not greater than 100 mg Cd/kg P (nitric acid derived) or 220mg Cd/kg P (phosphoric acid derived) or 280 mg Cd/kg P (sulphuric acid derived).

The fertiliser application rates (kg P/ha/yr) are based on the assumption that soil Bulk Density of soil equals 1.0. It should be noted that both pumice and peat are exceptional soils in the TFMS, due to low bulk density. Therefore, the cadmium loading rate per hectare, based on Figure 1 and Table 2, may result in a higher measurement of soil cadmium per kilogram of soil for these soils. It is recommended that the bulk density of very light soils also be taken into account when assessing the cadmium loading rate.

Figure 1: Product selection and maximum rate of average annual P application for soils at Tiers 1–4



Note: This approach is conservative in that it assumes all cadmium remains in the surface soil within a depth of 15 cm, with no soil system losses. It also assumes the cadmium levels in the phosphate fertiliser are always at the maximum allowable limit, when in fact they are kept below this level, to ensure it is not exceeded.

Table 2: Guide to fertiliser product selection

Product group for phosphate fertiliser	Assumed upper limit for cadmium concentration (mg Cd/kg P)	Phosphate fertiliser products
Direct Application Phosphate Rock	280	DAPR / RPR (Direct Application Phosphate Rock/ Reactive Phosphate Rock)
Sulphuric Acid Derived Products	280	Superphosphate Sulphur Super Potash Super Serpentine Superphosphate Superphosphate blends
Phosphoric Acid Derived Products	220	Triple Superphosphate DAP MAP
Nitric Acid Derived Products	100	Compound Fertiliser Prills

Note: Products in this table are examples of commonly used products. Check with your Certified Nutrient Management Adviser for more options.

Any specific phosphate fertiliser product, which has a 'certified' or 'declared' value for cadmium concentration, may be applied at the rate appropriate to the concentrations shown in the centre column above.

Example

Any 'sulfuric acid derived product' or 'Direct Application Phosphate Rock product', with a declared or certified cadmium level at or below the maximum limit for the 'phosphoric acid derived products', could be applied at the rate appropriate for the 'phosphoric acid derived products'. Any 'phosphoric acid derived product', which meets the maximum limits for the 'nitric acid derived products' could be applied at the rate appropriate for the 'nitric acid derived products'.

Plant cadmium uptake

No simple relationship exists between soil cadmium and plant uptake of cadmium. Plant uptake can vary depending on the crop species, crop cultivar, management actions, and a range of soil characteristics, including soil cadmium concentration, pH, zinc concentrations, organic matter, soil texture and more.

In addition to managing fertiliser, a number of other actions may be important for farmers or growers.

- Choice of crop or plant variety (plant species and variety can have a significant effect).
- Follow farm practices that minimise uptake (e.g. management of pH, organic matter, trace element levels, fertiliser placement).
- Monitoring soils to understand characteristics that influence plant uptake.
- Monitoring high risk crops, to understand the risk of exceeding food standards under local conditions (leafy vegetables tend to take up cadmium more readily than root crops. Fruit tend to have low cadmium uptake).

Endnotes and references

1 The CMG comprises representatives from government and primary industry: Ministry for Primary Industry, (including NZ Food Safety), Ministry for the Environment, Regional Councils, Beef & Lamb NZ, DairyNZ, Arable Food Industry Council, Horticulture NZ, Federated Farmers of NZ, Fertiliser Association NZ, Ballance Agri-nutrients, Ravensdown.

2 Review of the New Zealand Cadmium Management Strategy (May 2018), Mike McLaughlin and David Miller.

3 Report of the Cadmium Working Group (Aug 2008), Report One: Cadmium in New Zealand Agriculture (page 40).

4 Review of, and recommendations for, the proposed New Zealand Cadmium Management Strategy and Tiered Fertiliser Management System, **(**MAF Technical Paper No: 2011/03), Prepared for the Cadmium Working Group by Michael Warne, CSIRO.

Appendix 1: Soil Cadmium Sampling Protocols

GENERAL PRINCIPLES

Where a soil fertility monitoring programme already exists, add soil cadmium to the list of parameters tested. Farms should monitor soil cadmium at least once every 5 years. In the absence of an existing programme farmers should consider following this guide.

a) A soil sample comprises of 15–20 soil cores to either 7.5 cm depth for pastures or 15.0cm depth for cultivated soils, collected along a transect, or a grid which is representative of the monitor paddocks. The paddocks chosen should be representative of a Land Management Unit (LMU).

b) For phosphate fertiliser recommendations, an LMU is a distinct area which is managed in a similar way due to soil type, capability and function, and is of strategic importance to the farm in relation to phosphate fertiliser application.

c) It is expected that most farms will be represented by one LMU, and no more than 2 or 3 LMUs are expected unless the property is very large and diverse.

d) For each LMU it is anticipated there will be several representative soil samples (transects), at least two or three. Where Cd is included in the separate soil sample analyses, the mean of the soil cadmium results, is the correct value to use as a representative soil cadmium level for the LMU.

e) The advantage of analysing the samples (transects) separately is that the variability between the paddocks can be monitored. However, it is recognised that some farmers may seek to monitor one representative paddock for Cd within each LMU. The monitor paddock(s) for cadmium for each LMU, should be clearly identified and fixed.

f) When a greater understanding of variability on the farm is sought it would be best to sample no less than 6 paddocks (transects) per LMU and report each paddock Cd level separately. For example, when mean LMU soil cadmium trigger values (Tier levels 2, 3, 4) are being approached.

g) A graph of the soil cadmium results over time should be established for all LMUs.

COLLECTING SAMPLES

Soil samples should be collected by trained staff with sufficient skills to ensure samples are not biased and are representative of the LMUs on the farm.

Soil sampling must be conducted with care not to contaminate the sample with trace levels of extraneous chemicals or soil—including cross contamination between transects.

Note: products containing zinc are sources of cadmium contamination, notably galvanised iron.

- Use clean hands and sampling kits.
- Use stainless steel augers (avoid galvanised or zinc plated tools).
- Avoid unrepresentative areas, such as dung patches, stock campsites, fence lines, gateways, troughs, power pylons.
- Avoid old dumping grounds.
- Avoid sites with fertiliser/chemical spillage.
- Avoid sampling soon after fertiliser/lime applications (preferably more than 3 months).
- Horticultural herbicide/pesticide spray lines are treated as a separate block.

SAMPLE DEPTH

Sample depth is important because cadmium is known to accumulate in the surface profile.

Pastoral Land

In pastoral farming the surface 7.5 cm is routinely tested for fertiliser recommendations. This sample depth is consistent with the scientifically established calibration of the relationship between soil nutrient levels and pasture growth. Screening for cadmium to this depth using routine soil fertility monitoring procedures will allow a rapid survey of soil cadmium levels in pastoral soils, using existing procedures.

Where the soil cadmium assessment requires a critical and definitive measure of soil cadmium, 15 cm sampling depth is the required sampling depth (see below). Uniform soil mixing by means of ploughing is assumed to occur to a depth of 15 cm or more.

Horticultural and Arable Land

Fifteen centimetres is the standard soil sampling depth to determine fertiliser recommendations for horticultural and arable crops. Sampling to 15 cm using existing routine procedures will allow a survey of soil cadmium levels in horticultural and arable soil and will reliably represent what is available within the plant root zone.

Consumption of vegetable and grain produce represents the most likely pathway for exposure to cadmium for human health considerations, as cadmium accumulation in meat and milk products (other than kidneys and liver of livestock) is known to be very low. Therefore, in terms of human health considerations, sampling to a soil depth applicable to vegetable and arable crops provides the most meaningful measure of soil cadmium.

It is for these reasons 15 cm has been selected as the definitive sampling depth for the management of cadmium in agricultural soils.

Pastoral soils and uncultivated soils “Screening” sample depth	**= 7.5 cm cores**
Pastoral soils and uncultivated soils “Definitive” sample depth	**= 15 cm cores**
Horticultural, Arable and cultivated soils “Definitive” sample depth	**= 15 cm cores**

STORAGE OF SOIL SAMPLES SHOULD BE ARCHIVED

Separate labelled portions of the composite samples which are submitted for cadmium monitoring should be dried and stored in a sealed plastic bag, in cool dry conditions for subsequent reference and re-testing if required.

INFORMATION REQUIRED WITH SOIL SAMPLES FOR CADMIUM MONITORING

Each sample site should be recorded with GPS or marked reliably on a map.

Composite transect/grid samples must be clearly labelled with a unique identifying code and provide:

- Date
- Submitter
- Farm name
- Farm owner/manager
- Farm location (Rapid number) and/or GPS coordinates
- Unique Transect/Grid Identification Number
- Soil sample depth
- Soil type
- Current land use
- Proposed land use (next 1–5 years)

And preferably:

- Site land use history should it be available
- Fertiliser history should it be available

IANZ ACCREDITED LABORATORIES SHOULD ALWAYS BE USED

Precise and methodical sampling procedures and using an accredited laboratory should ensure that accurate and reproducible results are achieved.