Trace Elements in Bay of Plenty Soils

Prepared by Danilo Guinto, Environmental Scientist

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Cover Photo:
Soil trace element sampling in a dairy pasture

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Executive summary

Soil trace element sampling has recently been included in the Bay of Plenty's regular regional soil quality/health monitoring programme due to concerns regarding potential risk of accumulation associated with some past and present-day land use practices such as fertiliser application and disease control. Topsoil (0-10 cm) samples from existing soil quality monitoring sites were analysed for the trace elements arsenic, cadmium, chromium, copper, lead, mercury, nickel, uranium and zinc in 2009 and 2010. Trace element data from previous samplings (archived samples) were also included in order to show trends over time. The samples represented five land uses namely dairy, maize, sheep/beef, deer and kiwifruit.

Results for the 2009 and 2010 samplings indicate that for the land uses monitored, many of the topsoil trace element concentrations were below environmental guideline values. For cadmium in dairy pasture sites, however, 26% (5 out of 19 sites) of the sites have levels exceeding the 1 mg/kg guideline value which is a concern. This is a reflection of the continual use of phosphate fertilisers in this land use resulting in the accumulation of cadmium as a fertiliser impurity over time.

The temporal changes in mean trace element concentrations for all land uses were not significant. Mean values for each sampling year were all below the environmental guideline values for each element. For dairy pasture sites, there were increasing trends in cadmium and zinc concentrations over a 10-year period (1999-2009) but these increases were not statistically significant. In fact, for cadmium, mean concentrations in 2004 (0.76 mg/kg) and 2009 (0.75 mg/kg) were almost identical suggesting that cadmium concentration has not increased since 2004. In kiwifruit orchard sites, copper and zinc concentrations over the 10-year period (2000-2010) appear to be increasing but the increases were not statistically significant due to the small sample size. Nevertheless, this is will most likely be a concern particularly for copper which is now a widely used spray to control the *Pseudomonas* disease (Psa) of kiwifruit vines.

Background concentrations of trace elements from indigenous forest sites were generally lower than the initial concentrations from farmed soils at the commencement of the regional soil quality monitoring programme.

The ten-year soil quality monitoring programme is invaluable in providing information on changes in topsoil trace element levels and should continue well into the future.

For cadmium, farmers, landowners and other stakeholders should be guided by the Cadmium Management Strategy (MAF 2011, Rys 2011) which sets out approaches for reducing the risk of cadmium accumulation in New Zealand farming systems. It is recommended that farmers monitor cadmium concentrations in their soils and adopt fertiliser and soil management practices to reduce cadmium uptake by crops and pastures. These include: use of phosphate fertilisers with low levels cadmium levels, maintain soil pH at the upper recommended limits for crop type, maintain high organic matter content in the soil, alleviate any zinc deficiency in the soil, avoid fertiliser blends and irrigation water containing high levels of chloride, and the use of crop varieties which have a lower level of cadmium uptake.

Kiwifruit growers using copper sprays in their orchards to control Psa disease need to periodically monitor the copper levels in their soils. They should also keep abreast of research developments on alternative disease control strategies to reduce their dependence on copper sprays.

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Figures and Tables

Part 1: Introduction

Chemical elements occurring in soils at concentrations generally below 100 mg/kg are referred to as trace elements. When they are metallic with a specific gravity of more than 6 they are also known as heavy metals (Hooda 2010). Trace elements accumulate in soils either naturally through the weathering of minerals contained in their parent materials but they can become soil contaminants introduced through a range of agricultural and industrial activities. Some trace elements are essential for the growth of plants and animals and are termed micronutrients (e.g. copper and zinc). Others are not (e.g. cadmium and arsenic). However, both essential and non-essential elements can become toxic to plants and animals at elevated concentrations. It is in this context that the monitoring of soil trace elements is important now and in the future. Summary information on the occurrence, uses, effects on human health and exposure pathways of trace elements of concern are provided in Appendix 1. Taylor (2007), Taylor (2011) and Taylor et al. (2011) distinguished between two groups of trace elements that are of concern in agricultural and horticultural land uses: (1) those associated with the use of phosphate fertilisers (cadmium and uranium) and (2) those linked to the use of agricultural chemicals used in farming (arsenic, chromium, copper, lead, mercury, nickel and zinc).

Trace element sampling has recently been included in the Bay of Plenty's regular regional soil quality/health monitoring programme (Guinto 2009; 2010) due to concerns regarding the potential risk of accumulation associated with some past and present-day land use practices such as fertiliser application and disease control. For example, cadmium is an unavoidable contaminant in phosphate fertilisers, facial eczema treatment contains high levels of zinc, and copper is used as a fungicide in orchards. Copper is also now commonly used to combat the recently discovered *Pseudomonas* bacterial disease (*Pseudomonas syringae* pv *actinidiae* or Psa) of kiwifruit. Other regional councils (e.g. Tasman, Marlborough and Waikato) have also included trace element sampling as part of their soil quality monitoring programmes (Burton 2009; Gray 2010; Taylor et al. 2010; Taylor 2011; Taylor et al. 2011).

Previous work on the trace element concentrations of soils in agricultural and horticultural areas of the Bay of Plenty (Solutions in Environmental Management (SEM) 2005) has indicated that copper and arsenic were the elements that most frequently exceeded the selected "trigger levels" ""or "guideline values" for agriculture and residential land uses. Out of 103 topsoil (0-7.5 cm) samples analysed, an exceedance rate of 15.5% was found for copper while it was 13% for arsenic. It recommended further investigation of agricultural and horticultural lands prior to development to more sensitive land uses such as residential. More recent research on kiwifruit orchards in the Bay of Plenty (Benge and Manhire 2011) has shown that, on average, the topsoil (0-15 cm) concentrations of trace metals were below the guideline values. However, concern was expressed for arsenic, copper and cadmium as their average concentrations were close (50-63%) to their respective guideline values. It was noted that arsenic could be potentially leaching into soils from treated posts, cadmium accumulating from phosphate fertilisers and copper from sprays used in orchards.

This report focuses on the results of the trace element sampling in farmed soils covering dairy pasture and maize cropping sites in 2009 and drystock (sheep/beef and deer pastures) and kiwifruit orchards in 2010. It also discusses the temporal changes of trace element concentrations of the farmed sites over a ten-year period. In addition, a comparison between the initial concentrations of trace elements in farmed sites (1999/2000) relative to initial concentrations in indigenous forest sites (2000) that are considered background levels was made.

Part 2: Materials and Methods

2.1 Soil sampling and analyses

Topsoil samples (0-10 cm) were collected from the regional soil quality sampling sites in 2009 and 2010 (Figure 1 and Appendix 2). In 2009, dairy pasture and maize cropping sites were sampled. An additional 6 new maize cropping sites were also sampled in that year to reflect the growing importance of this land use in the region (Guinto 2009). In 2010, sheep/beef pasture, deer pasture, and kiwifruit orchard sites were sampled (Guinto 2010). The sampling procedure for trace elements followed the standard protocol for New Zealand soil quality sampling for chemical analysis (Hill and Sparling 2009). Briefly, a 50-m transect was established in each site. Samples were collected with a step-on soil sampler at 2-m intervals along the 50-m transect. The 25 individual samples collected per site were bulked and mixed thoroughly in a plastic bag. It should be noted that the standard 0-10 cm topsoil sampling depth represents a compromise for the various land uses since pasture soils (dairy, sheep/beef and deer) are normally sampled at 0-7.5 cm while maize and kiwifruit soils are sampled at 0-15 cm.

The samples were submitted to Hill Laboratories in Hamilton City for the analysis of the trace metals arsenic (As), cadmium (Cd), chromium (Cd), copper (Cu), chromium (Cr), lead (Pb), mercury (Hg), nickel (Ni), Uranium (U), and zinc (Zn). The soils were air-dried at 35°C and screened to pass a 2 mm sieve. Trace element concentrations were determined by digesting the samples in nitric/hydrochloric acid and analysing the trace elements in the digest by inductively coupled plasma mass spectrometry (also known as US Environmental Protection Agency Method 200.2). The concentrations were reported as total recoverable metals in mg/kg dry soil (Kim and Taylor 2009).

2.2 Data analyses

Mean trace element concentrations by land use class were compared with New Zealand environmental guideline values (NZWWA 2003) for all trace elements except uranium wherein the Canadian soil guideline value was used (CCME 2007). Previous trace element data from all land uses considered were also used in order to show trends over time (i.e. from selected archived soil samples collected in 1999/2000, 2004, 2005, and 2006 which were also submitted for analysis). Analysis of variance (ANOVA) was applied to the data set to detect if there are significant changes in mean trace element concentrations over time. Prior to ANOVA, the data were tested for normality and homogeneity of variance (Levene's test).

To detect if trace element enrichment occurs as a result of farming, initial (1999/2000) trace element concentrations from the various land uses were compared with background levels obtained from indigenous forest sites collected in 2000. Student's t-test (with unequal group variances assumed) was used to assess if the difference in means between each land use and the indigenous forest sites were significant.

Some trace element results (e.g. mercury) were below the detection limit. In these cases, the values were replaced by half the detection limit (e.g. 0.5 mg/kg was used if the detection limit is 1 mg/kg) (Berthouex and Brown 2002). In terms of number of samples, it should be noted that the initial 1999/2000 sampling for dairy sites included only 11 samples analysed whereas the subsequent samplings included 19 samples. Fewer number of samples analysed over time also occurred in maize, sheep/beef, deer and kiwifruit sites as a result of residential land use conversion and a few landowners not allowing access to their properties during later sampling.

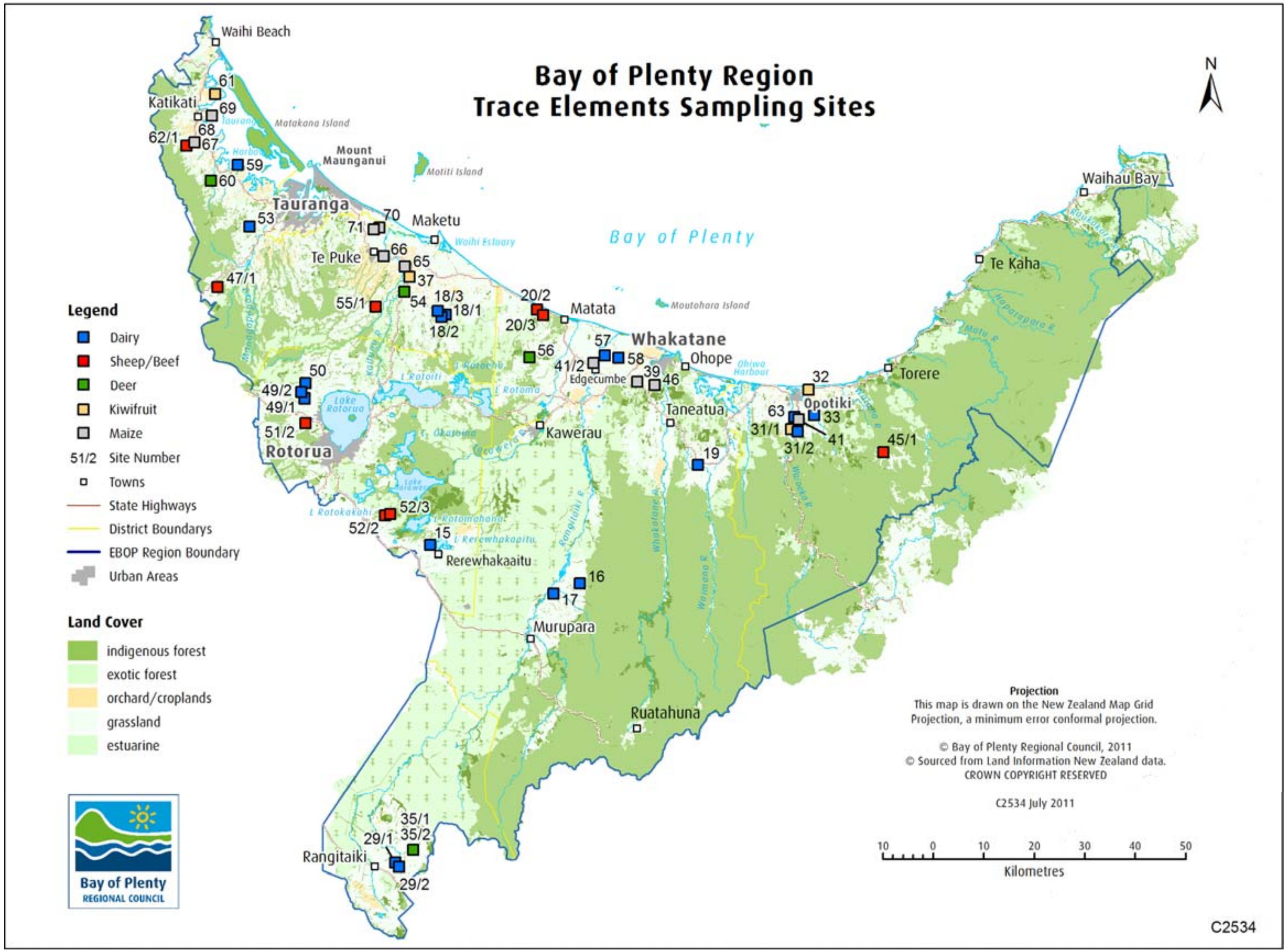

Figure 1 *Trace element sampling sites, 2009-2010.*

Part 3: Results and Discussion

3.1 Trace element concentrations under different land uses

3.1.1 Dairy pasture sites

Table 1 shows the trace element concentrations of topsoil from dairy pasture sites sampled in 2009. In general, mean values of all trace elements were below the guideline values. However, arsenic, cadmium and zinc have sites that exceeded their respective guideline values. In particular, for cadmium, 26% (5 out of 19 sites) have levels exceeding the 1 mg/kg guideline value which is a concern. In nearby Waikato Region with similar soils, only 12% of the samples exceeded the guideline value (Taylor et al. 2010). This is a reflection of the continual use of phosphate fertilisers in dairy pastures in the Bay of Plenty which has been accumulating over time since cadmium is an impurity in phosphate fertilisers. A similar result was obtained by Longhurst et al. (2004) in a national survey of trace elements in pastoral topsoils (0-7.5 cm) where farmed soils had significantly higher total cadmium concentration than non-farmed soils (0.44 mg/kg vs. 0.20 mg/kg). It should also be noted that the mean concentration of cadmium is 75% of its guideline value.

It should be observed that most environmental guideline values for trace elements are based on their total contents (i.e. total recoverable values). However, the behaviour of trace elements in the environment is determined by their specific physicochemical forms rather than their total concentration. Also, the availability of trace elements to plants is dependent on many factors so that trace element contents of plants are only poorly related to total elemental concentrations in soil. Soil physical, chemical and biological processes will determine the speciation, redistribution, mobility and ultimately the bioavailability of trace elements (Tack 2010). Therefore, exceeding an environmental guideline value should be viewed as an early warning signal and does not necessarily indicate that toxicities to plants and animals will be observed. In fact, McLaughlin et al. (2011) prefers the use of the term soil quality standard (SQS) and defined it to mean a threshold concentration of trace element in soil above which some action is required (e.g., further investigation, toxicity assessment, remediation, etc.).

Rys (2011) and MAF (2011) described the national cadmium management strategy which is the result of a 4-year deliberation among relevant institutions across New Zealand. He concluded that the reality is that cadmium is an impurity that cannot be totally removed from the manufacture of phosphate fertilisers although the Cd content of present-day phosphate fertilisers in New Zealand now averages about 180 mg Cd per kg of P which is below the voluntary 280 mg Cd per kg of P limit set in 1997. The objective of the strategy is to ensure that Cd in rural production poses minimal risks to health, trade, land use flexibility, and the environment over the next 100 years. A key component of this strategy is the tiered fertiliser management strategy under which specific management actions will be linked to four trigger values of soil cadmium (Appendix 3).

3.1.2 Maize cropping sites

Table 2a shows the trace element concentrations of topsoil from maize cropping sites sampled in 2009. The mean concentrations of all trace elements were all well below the guideline values and there were no sites that exceeded the guideline values. Similar results were observed in Waikato Region for arable soils (Taylor et al. 2010).

Table 2b shows the trace element concentrations of topsoil from additional maize cropping sites added in 2009. The mean concentrations of all trace elements were similar to those of the original sites (Table 2a). Also, the concentrations were all well below the guideline values.

Table 1 *Mean topsoil (0-10 cm) trace element concentrations of dairy pasture sites in 2009.*

Element	**Mean (Std Error) (mg/kg)**	**Guideline value (mg/kg)**	**Total no. of sites**	**No. of sites above guideline value**	**Percentage of sites above guideline value**
Arsenic	4.9 (1.2)	20	19	1	5.3
Cadmium	0.75 (0.09)	1	19	5	26.3
Chromium	7.6 (0.8)	600	19	0	0
Copper	16.1 (3.7)	100	19	0	0
Lead	5.6 (0.6)	300	19	0	0
Mercury	0.07 (0.01)	1	19	0	0
Nickel	6.1 (1.0)	60	19	0	0
Uranium	1.51 (0.14)	23	19	0	0
Zinc	72.0 (17.8)	300	19	1	5.3

Table 2a *Mean topsoil (0-10 cm) trace element concentrations of maize cropping sites in 2009.*

Element	**Mean (Std Error) (mg/kg)**	**Guideline value (mg/kg)**	**Total no. of sites**	**No. of sites above guideline value**	**Percentage of sites above guideline value**
Arsenic	4.9 (0.8)	20	5	0	0
Cadmium	0.29 (0.02)	1	5	0	0
Chromium	8.3 (1.4)	600	5	0	0
Copper	10.4 (1.7)	100	5	0	0
Lead	9.2 (1.8)	300	5	0	0
Mercury	0.07 (0.01)	1	5	0	0
Nickel	6.2 (1.3)	60	5	0	0
Uranium	1.02 (0.13)	23	5	0	0
Zinc	41.1 (7.2)	300	5	0	0

Table 2b *Mean topsoil (0-10 cm) trace element concentrations of additional maize cropping sites in 2009.*

Element	Mean (Std Error) (mg/kg)	Guideline value (mg/kg)	Total no. of sites	No. of sites above guideline value	Percentage of sites above guideline value
Arsenic	3.7 (1.3)	20	6	0	0
Cadmium	0.35 (0.14)	1	6	0	0
Chromium	4.6 (1.0)	600	6	0	0
Copper	13.4 (4.2)	100	6	0	0
Lead	6.8 (1.4)	300	6	0	0
Mercury	0.09 (0.02)	1	6	0	0
Nickel	2.8 (0.8)	60	6	0	0
Uranium	1.15 (0.18)	23	6	0	0
Zinc	36.7 (7.9)	300	6	0	0

Table 3 *Mean topsoil (0-10 cm) trace element concentrations of sheep/beef pasture sites in 2010.*

Element	Mean (Std Error) (mg/kg)	Guideline value (mg/kg)	Total no. of sites	No. of sites above guideline value	Percentage of sites above guideline value
Arsenic	5.8 (2.1)	20	9	0	0
Cadmium	0.36 (0.06)	1	9	0	0
Chromium	3.3 (0.3)	600	9	0	0
Copper	6.9 (0.5)	100	9	0	0
Lead	4.6 (0.4)	300	9	0	0
Mercury	0.07 (0.01)	1	9	0	0
Nickel	2.5 (0.7)	60	9	0	0
Uranium	0.80 (0.09)	23	9	0	0
Zinc	28.2 (2.4)	300	9	0	0

Table 4 *Mean topsoil (0-10 cm) trace element concentrations of deer pasture sites in 2010.*

Element	Mean (Std Error) (mg/kg)	Guideline value (mg/kg)	Total no. of sites	No. of sites above guideline value	Percentage of sites above guideline value
Arsenic	2.6 (0.6)	20	3	0	0
Cadmium	0.53 (0.08)	1	3	0	0
Chromium	3.7 (0.8)	600	3	0	0
Copper	14.7 (5.0)	100	3	0	0
Lead	3.6 (1.1)	300	3	0	0
Mercury	0.05 (0.01)	1	3	0	0
Nickel	4.0 (0.8)	60	3	0	0
Uranium	1.00 (0.10)	23	3	0	0
Zinc	26.8 (9.1)	300	3	0	0

Table 5 Mean topsoil (0-10 cm) trace element concentrations of kiwifruit orchard sites in 2010.

Element	Mean (Std Error) (mg/kg)	Guideline value (mg/kg)	Total no. of sites	No. of sites above guideline value	Percentage of sites above guideline value
Arsenic	6.8 (1.1)	20	5	0	0
Cadmium	0.66 (0.15)	1	5	1	20.0
Chromium	9.5 (1.4)	600	5	0	0
Copper	42.6 (16.0)	100	5	1	20.0
Lead	7.7 (1.0)	300	5	0	0
Mercury	0.08 (0.02)	1	5	0	0
Nickel	6.9 (1.7)	60	5	0	0
Uranium	1.29 (0.21)	23	5	0	0
Zinc	96.4 (11.6)	300	5	0	0

3.1.3 Sheep/beef pasture sites

Table 3 shows the trace element concentrations of topsoil from sheep/beef pasture sites sampled in 2010. The mean concentrations of all trace elements were all well below the guideline values and there were no sites that exceeded the guideline values. In the Waikato region, Taylor et al. (2010) reported that 16% of drystock pasture sites exceeded the cadmium guideline value while 2% of the sites exceeded the arsenic guideline value.

3.1.4 Deer pasture sites

Table 4 shows the trace element concentrations of topsoil from deer pasture sites sampled in 2010. The mean concentrations of all trace elements were all well below the guideline values and there were no sites that exceeded the guideline values. It is noted, however, that the mean cadmium concentration was 53% of the guideline value.

3.1.5 Kiwifruit orchard sites

Table 5 shows the trace element concentrations of topsoil from kiwifruit orchard sites sampled in 2010. The mean concentrations of all trace elements were below the guideline values. However, for cadmium and copper, 1 out of 5 sites (20%) exceeded the respective elemental guideline values. Similar percentages were obtained by Taylor et al. (2010) in the Waikato where 25% of horticultural sites exceeded the guideline values for both cadmium and copper.

3.2 Temporal changes in trace element concentrations under different land uses

3.2.1 Dairy pasture sites

Table 6 shows the temporal changes in mean trace element concentrations in dairy pasture sites. Mean values for each sampling year were all below the environmental guideline values for each element. There were no statistically significant changes in the concentration of all trace elements measured. There were increasing trends in cadmium and zinc concentrations over a 10-year period but these increases were not statistically significant. In fact, for cadmium, mean concentrations in 2004 (0.76 mg/kg) and 2009 (0.75 mg/kg) were almost identical suggesting that cadmium concentration has not increased since 2004.

3.2.2 Maize cropping sites

Table 7 shows the temporal changes in mean trace element concentrations in maize cropping sites. Mean values for each sampling year were all below the environmental guideline value for each element. There were no statistically significant changes in the concentration of all trace elements measured. Copper concentration over the 10-year period appears to be decreasing but the decrease was not statistically significant.

3.2.3 Sheep/beef pasture sites

Table 8 shows the temporal changes in mean trace element concentrations in sheep/beef sites. Mean values for each sampling year were all below the environmental guideline value for each element. There were no statistically significant changes in the concentration of all trace elements measured. Zinc concentration over the 10-year period appears to be decreasing but the decrease was not statistically significant.

Table 6 Temporal changes in mean topsoil trace element concentrations (mg/kg) of dairy pasture sites.

Element	**Year**			***P* value**	**Guideline value (mg/kg)**
	1999/2000 (n=11)	**2004 (n=19)**	**2009 (n=19)**		
Arsenic	5.3 (1.3)	5.3 (1.4)	4.9 (1.2)	0.974 ns	20
Cadmium	0.68 (0.14)	0.76 (0.13)	0.75 (0.09)	0.905 ns	1
Chromium	7.7 (0.9)	8.0 (0.8)	7.6 (0.8)	0.949 ns	600
Copper	16.4 (3.0)	12.8 (2.4)	16.1 (3.7)	0.682 ns	100
Lead	6.6 (0.8)	5.6 (0.7)	5.6 (0.6)	0.570 ns	300
Mercury	0.07 (0.01)	0.07 (0.01)	0.07 (0.01)	0.991 ns	1
Nickel	5.7 (1.0)	5.7 (0.8)	6.0 (1.0)	0.965 ns	60
Uranium	1.43 (0.22)	1.46 (0.14)	1.51 (0.14)	0.937 ns	23
Zinc	51.7 (8.0)	73.0 (18.5)	72.4 (17.8)	0.693 ns	300

ns = not significant

Numbers in parenthesis are standard errors

Table 7 Temporal changes in mean topsoil trace element concentrations (mg/kg) of maize sites.

Element	Year				*P* value	Guide-line Value (mg/kg)
	2000 (n=6)	2004 (n=6)	2006 (n=6)	2009 (n=5)		
Arsenic	6.2 (0.8)	6.0 (0.7)	6.3 (0.7)	4.9 (0.8)	0.601 ns	20
Cadmium	0.23 (0.02)	0.27 (0.04)	0.32 (0.03)	0.29 (0.02)	0.274 ns	1
Chromium	8.5 (1.3)	9.7 (1.6)	9.7 (1.5)	8.3 (1.4)	0.854 ns	600
Copper	15.0 (1.4)	12.7 (1.8)	12.5 (2.0)	10.4 (1.7)	0.380 ns	100
Lead	9.3 (2.2)	10.4 (2.8)	9.8 (2.3)	9.2 (1.8)	0.983 ns	300
Mercury	0.06 (0.01)	0.07 (0.01)	0.08 (0.02)	0.07 (0.01)	0.900 ns	1
Nickel	6.8 (1.1)	7.2 (1.3)	6.8 (1.3)	6.2 (1.3)	0.966 ns	60
Uranium	0.90 (0.10)	0.95 (0.11)	1.02 (0.11)	1.02 (0.13)	0.854 ns	23
Zinc	47.0 (7.7)	48.0 (9.6)	52.5 (10.5)	41.1 (7.2)	0.859 ns	300

ns = not significant

Numbers in parenthesis are standard errors

Note: New maize soil samples collected in 2009 were not included in this data set as they only represent initial values for that year.

Table 8 Temporal changes in mean topsoil trace element concentrations (mg/kg) of sheep/beef pasture sites.

Element	Year			*P* value	Guideline value (mg/kg)
	2000 (n=8)	2005 (n=10)	2010 (n=9)		
Arsenic	7.1 (2.9)	7.0(2.6)	5.8 (2.1)	0.713 ns	20
Cadmium	0.38 (0.08)	0.43 (0.07)	0.36 (0.06)	0.567 ns	1
Chromium	3.9 (0.5)	4.10 (0.31)	3.28 (0.29)	0.199 ns	600
Copper	9.8 (0.8)	7.50 (0.54)	6.89 (0.54)	0.968 ns	100
Lead	5.9 (0.5)	5.82 (0.61)	4.62 (0.44)	0.387 ns	300
Mercury	0.08 (0.02)	0.10 (0.02)	0.07 (0.01)	0.417 ns	1
Nickel	1.75 (0.49)	1.60 (0.34)	2.53 (0.73)	0.337 ns	60
Uranium	0.82 (0.11)	1.03 (0.11)	0.80 (0.09)	0.667 ns	23
Zinc	35.2 (4.8)	31.6 (3.2)	28.2 (2.4)	0.140 ns	300

ns = not significant

Numbers in parenthesis are standard errors

Table 9 Temporal changes in mean topsoil trace element concentrations (mg/kg) of deer pasture sites.

Element	Year			*P* value	Guideline Value (mg/kg)
	2000 (n=4)	2005 (n=4)	2010 (n=3)		
Arsenic	2.8 (0.6)	3.2 (0.5)	2.6 (0.6)	0.695 ns	20
Cadmium	0.60 (0.11)	0.60 (0.07)	0.53 (0.08)	0.841 ns	1
Chromium	4.2 (0.8)	4.25 (0.48)	3.67 (0.82)	0.808 ns	600
Copper	15.2 (4.0)	18.25 (5.41)	14.70 (5.01)	0.858 ns	100
Lead	4.5 (1.0)	4.82 (1.11)	3.61 (1.06)	0.742 ns	300
Mercury	0.05 (<0.01)	0.05 (<0.01)	0.05 (0.01)	0.692 ns	1
Nickel	2.8 (1.0)	2.2 (0.8)	4.0 (0.8)	0.728 ns	60
Uranium	1.05 (0.19)	1.28 (0.19)	1.00 (0.10)	0.547 ns	23
Zinc	32.0 (5.6)	34.2 (8.2)	26.80 (9.11)	0.799 ns	300

ns = not significant

Numbers in parenthesis are standard errors

Table 10 Temporal changes in mean topsoil trace element concentrations (mg/kg) of kiwifruit orchard sites.

Element	Year			*P* value	Guideline Value (mg/kg)
	2000 (n=6)	2005 (n=6)	2010 (n=5)		
Arsenic	5.3 (0.5)	5.3 (0.8)	6.8 (1.1)	0.408 ns	20
Cadmium	0.65 (0.12)	0.68 (0.12)	0.66 (0.15)	0.982 ns	1
Chromium	7.7 (1.2)	8.7 (1.2)	9.5 (1.4)	0.602 ns	600
Copper	24.0 (4.2)	35.3 (9.9)	42.6 (16.0)	0.473 ns	100
Lead	9.6 (1.6)	9.3 (1.6)	7.7 (1.0)	0.647 ns	300
Mercury	0.08 (0.02)	0.08 (0.02)	0.08 (0.02)	0.959 ns	1
Nickel	5.5 (1.3)	6.2 (1.6)	6.9 (1.7)	0.830 ns	60
Uranium	1.18 (0.20)	1.32 (0.22)	1.29 (0.21)	0.894 ns	23
Zinc	72.0 (10.1)	82.2 (10.4)	96.4 (11.6)	0.311 ns	300

ns = not significant

Numbers in parenthesis are standard errors

3.2.4 Deer pasture sites

Table 9 shows the temporal changes in mean trace element concentrations in deer pasture sites. Mean values for each sampling year were all below the environmental guideline value for each element. There were no statistically significant changes in the concentration of all trace elements measured.

3.2.5 Kiwifruit orchard sites

Table 10 shows the temporal changes in mean trace element concentrations in kiwifruit orchard sites. Mean values for each sampling year were all below the environmental guideline values for each element. There were no statistically significant changes in the concentration of all trace elements measured. Copper and zinc concentrations over the 10-year period appear to be increasing but the increases were not statistically significant due to the small sample size (n=6 or 5). While not statistically significant, the increase in mean copper concentration is almost 78% over the 10-year period. This is will more likely be a concern since copper is now a widely used spray to control the pseudomonas disease (Psa) of kiwifruit vines.

3.3 Initial trace element concentrations under farmed land uses relative to background levels

Table 11 shows the initial concentrations (1999/2000 sampling) of trace elements in farmed sites relative to initial background levels in indigenous forest sites (2000 sampling). This gives an indication of the degree of trace element contamination already associated with agricultural land uses at the commencement of the regional soil quality monitoring programme. With a few exceptions (e.g. arsenic, mercury), indigenous forest topsoils have lower concentrations of trace elements compared with farmed topsoils.

By further aggregating the farmed sites and doing a pooled t-test, a more simplified comparison between farmed and unfarmed sites is presented in Table 12 which shows that cadmium, chromium, nickel, uranium and zinc levels are significantly elevated in farmed sites relative to background levels in indigenous forest sites at the start of the regional soil quality monitoring programme. Similar results were obtained by Taylor (2011) and Taylor et al. (2011) for the Waikato region.

3.4 Comparison of background levels of trace elements in indigenous forest sites with other studies

Table 13 compares the measured background levels of trace elements in the Bay of Plenty region (mg/kg) with those reported earlier by SEM (2005). Background levels for the nearby Waikato region with similar soils (Taylor and Kim 2009) were also included for comparative purposes. When corrected to a common depth of 0-10 cm, there is generally good agreement between the background levels of trace elements in this report and the SEM report except for arsenic and copper which are higher in this report. Similarly, good agreement between background levels in this report and the Waikato region background levels are apparent except for chromium and nickel which are much lower for the Bay of Plenty region.

Table 11 Initial mean topsoil (0-10 cm) concentrations of trace elements (mg/kg) under farmed land uses relative to background levels in indigenous forests.

Element	**Indigenous Forest 2000 (n=5)**	**Dairy 1999/2000 (n=11)**	**Maize 2000 (n=6)**	**Sheep/ Beef 2000 (n=8)**	**Deer 2000 (n=4)**	**Kiwifruit 2000 (n=6)**	**Guideline Value (mg/kg)**
Arsenic	6.4	5.3	6.2	7.1	2.8	5.3	20
Cadmium	0.08	0.68	0.23	0.38	0.60	0.65	1
Chromium	3.0	7.7	8.5	3.9	4.2	7.7	600
Copper	15.0	16.4	15.0	9.8	15.2	24.0	100
Lead	8.4	6.6	9.3	5.9	4.5	9.6	300
Mercury	0.14	0.07	0.06	0.08	0.05	0.08	1
Nickel	1.4	5.7	6.8	1.8	2.8	5.5	60
Uranium	0.52	1.43	0.90	0.82	1.05	1.18	23
Zinc	29.6	51.7	47.0	35.2	32.0	72.0	300

Table 12 *Comparison of initial mean topsoil (0-10 cm) concentrations of trace elements (mg/kg) in indigenous forest sites and farmed sites (pooled data).*

Element	**Indigenous forest sites in 2000 (n=5)**	**Farmed sites in 1999/2000 (n=35)**	**Significance (*P* value)**
Arsenic	6.4 (2.5)	5.6 (0.8)	0.765 ns
Cadmium	0.08 (0.03)	0.52 (0.06)	<0.001 **
Chromium	3.0 (0.7)	6.6 (0.5)	0.003 **
Copper	15.0 (1.0)	15.8 (1.5)	0.660 ns
Lead	8.4 (1.0)	7.2 (0.6)	0.328 ns
Mercury	0.14 (0.04)	0.07 (0.01)	0.130 ns
Nickel	1.4 (0.4)	4.6 (0.6)	0.000 **
Uranium	0.52 (0.15)	1.11 (0.09)	0.011 *
Zinc	29.6 (6.0)	48.4 (4.0)	0.030 *

Numbers in parenthesis are standard errors

ns = not significant

* = significant at 5% level

** = significant at 1% level

Table 13 *Comparison of measured background levels of trace elements in the Bay of Plenty region (mg/kg) with those reported by SEM (2005) and the Waikato region.*

Element	**1999/2000 indigenous forest samples (n=5) (0-10 cm)**	**SEM Report (n=25) (0-7.5 cm)**	**SEM Report (n=25) (Corrected to 0-10 cm)**	**Waikato (Taylor and Kim 2009) (0-10 cm)**
Arsenic	6.4	4.92	3.7	5.1
Cadmium	0.08	0.14	0.10	0.11
Chromium	3.0	4.48	3.4	18
Copper	15.0	10.08	7.6	16
Lead	8.4	12.55	9.4	11
Mercury	0.14	No data	No data	0.19
Nickel	1.40	1.64	1.23	3.9
Uranium	0.52	No data	No data	0.79
Zinc	29.6	45.04	33.8	28

Part 4: Conclusion and Recommendations

For the land uses monitored, many of the topsoil trace element concentrations were below environmental guideline values. The temporal changes in mean trace element concentrations were not significant. Mean values for each sampling year were all below the environmental guideline values for each element. For dairy pasture sites, there were increasing trends in cadmium and zinc concentrations over a 10-year period (1999-2009) but these increases were not statistically significant. In fact, for cadmium, mean concentrations in 2004 (0.76 mg/kg) and 2009 (0.75 mg/kg) were almost identical suggesting that cadmium concentration has not increased since 2004. However, in the 2009 sampling, 26% (5 out of 19 sites) have cadmium levels exceeding the 1 mg/kg guideline value which is a concern. In kiwifruit orchard sites, copper and zinc concentrations over the 10-year period (2000-2010) appear to be increasing but the increases were not statistically significant due to the small sample size. Nevertheless, this is will most likely be a concern particularly for copper which is now a widely used spray to control the *Pseudomonas* disease (Psa) of kiwifruit vines.

Topsoil trace element concentrations were generally higher in agricultural land uses relative to background concentrations in indigenous forest sites reflecting that enrichment is attributable to land management practices that added detectable quantities of trace elements to soils.

The ten-year soil quality monitoring programme is invaluable in providing information on changes in topsoil trace element levels and should continue well into the future.

For cadmium, farmers, landowners and other stakeholders should be guided by the Cadmium Management Strategy (MAF 2011, Rys 2011) which sets out approaches for reducing the risk of cadmium accumulation in New Zealand farming systems. A key component of this strategy is the tiered fertiliser management strategy under which specific management actions will be linked to four trigger values (tiers) for the cadmium concentration in the soil (Appendix 3).

It is recommended that farmers monitor cadmium concentrations in their soils and adopt fertiliser and soil management practices to reduce cadmium uptake by crops and pastures. These include: use of phosphate fertilisers with low cadmium levels, maintain soil pH at the upper recommended limits for crop type, maintain high organic matter content in the soil, alleviate any zinc deficiency in the soil, avoid fertiliser blends and irrigation water containing high levels of chloride, and the use of crop varieties which have a lower level of cadmium uptake (Tikkisetty 2011).

Kiwifruit growers using copper sprays in their orchards to control Psa disease need to periodically monitor the copper levels in their soils. They should also keep abreast of research developments on alternative disease control strategies to reduce their dependence on copper sprays.

Part 5: References

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Appendices

Appendix 1 – Background information on trace elements regarded as contaminants or potential contaminants in the soil*

Element	Occurrence	Uses	Exposure Pathways and Effects on Human Health
Arsenic (As)	A naturally occurring element in the earth's crust. Also found in plants and animals	Timber preservation and manufacture of pesticides	Exposure can occur through breathing sawdust or smoke from wood treated with As and ingesting contaminated food or water. Inorganic As compounds are more toxic than organic compounds. Breathing high levels of As can irritate the lungs while ingestion can cause death. Inorganic As is a human carcinogen.
Cadmium (Cd)	A naturally occurring element in soils and rocks. It is found in coal and mineral (phosphate) fertilisers.	It is used in batteries, pigments, metal coatings and plastics.	Exposure to Cd is mostly an occupational nature and associated with the Cd manufacturing industry. Breathing Cd in cigarette smoke doubles the average daily intake. Breathing high levels of Cd can damage the lungs. Ingestion of contaminated food or water can irritate the stomach. Long-term exposure can lead to a build-up of Cd in kidneys and cause kidney disease.
Chromium (Cr)	A naturally occurring element found in rocks, soils, volcanic dusts and gases, and plants and animals. The form of Cr known as Cr(III) is the most stable and most Cr in the environment is in this form	Metallic Cr is used in making steel. Cr compounds are used in chrome plating, dyes and pigments, leather tanning and wood preserving.	Exposure can occur through breathing in contaminated air associated with industries that use Cr. Exposure may also occur through ingesting contaminated food or water. Possible health effects depend on the type of Cr one is exposed to. No health effects are associated with exposure to Cr(III). Breathing high levels of Cr(VI) can damage the nose while ingesting it can cause stomach ulcers, convulsions, and kidney and liver damage. Cr is classified as a human carcinogen.
Copper (Cu)	Cu occurs naturally in rocks, soil, water, and air as well as in plants and animals	Present in coins, electrical wiring, water pipes and some metal alloys. Copper compounds are used in plant	Exposure can occur through breathing air, drinking water, eating food, and by skin contact with air, soil, water and substances enriched in Cu. Inhalation or skin contact with Cu-containing dust can occur in the

Element	Occurrence	Uses	Exposure Pathways and Effects on Human Health
		fungicides, for water treatment and as preservatives for wood, leather and fabrics	copper mining industry and the welding of Cu metal. Exposure can occur through the use of garden or farm products to control plant diseases. Low levels are essential for maintaining good health. High levels can cause irritation of the nose, mouth and eyes, and nausea and stomach upsets.
Lead (Pb)	Naturally occurring metal. Distributed in the environment from the burning of fossil fuels, mining and manufacturing	Production of batteries, ammunition and metal products. Can be present in fuels, paints and ceramic products.	Exposure can occur through breathing workplace air or dust, eating contaminated food or drinking contaminated water. Exposure may also occur through ingesting Pb-based paint chips and ingesting or contacting contaminated soil. Pb affects the central nervous system, the kidneys and blood cells. It can lead to hypertension, reproductive toxicity and developmental defects. It is classified as a possible human carcinogen based on animal studies.
Mercury (Hg)	A naturally occurring metal. It exists as metallic mercury, which is the shiny silver liquid found in thermometers, and as Hg salts and organic Hg compounds. A form of Hg (methyl Hg) can be formed in soil by soil bacteria	Used in manufacturing, mostly in the production of chlorine gas and caustic soda, and is found in thermometers, dental fillings, some light bulbs and batteries. Hg can be distributed in the environment through the burning of coal and waste.	Exposure to Hg can occur through breathing in vapours related to dental, health and some chemical industries and vapours from Hg spills and some incinerators. Exposure can also occur through eating shellfish contaminated with methyl Hg and ingesting and contacting contaminated soil. Hg affects the nervous system and high levels can permanently damage the brain, kidneys and developing foetus. The inhalation of Hg vapours is particularly harmful. Certain forms of Hg are classified as possible human carcinogens based on animal studies.
Nickel (Ni)	An abundant naturally occurring element found in soils and is emitted from volcanoes.	Used in the manufacture of stainless steel and metal alloys. Ni compounds are used for Ni plating, the manufacture of some batteries and some chemicals.	Exposure can occur through eating food or drinking water containing Ni and by skin contact with soil or metals containing Ni. Exposure may also occur through breathing contaminated air and smoking tobacco containing Ni. The most common harmful effect is allergic skin reactions due to direct contact with Ni-containing items such as some jewellery.

Element	Occurrence	Uses	Exposure Pathways and Effects on Human Health
			Breathing large amounts of Ni compounds in Ni refineries can cause chronic bronchitis and lung and nasal sinus cancers. Ni compounds are classified as carcinogens.
Uranium (U)**	The heaviest of the naturally occurring elements; weakly radioactive. Present in the earth's crust at an average concentration of 3 mg/kg. Present in soils as the uranyl cation (UO_2^{2+}) with a +6 oxidation state. Like Cd, also an impurity in phosphate fertilisers	Used to fuel nuclear power plants, manufacture of ammunitions, military vehicles, radiation shields, chemical catalysts, glassware and ceramics	Breathing air containing U dusts or eating substances containing U are the main exposure pathways. Exposure can result in both chemical and radiological toxicity. The main chemical effect is damage to kidney cells while the radiological effect of long-term exposure at high concentrations is the high probability of developing radiation-induced cancer.
Zinc (Zn)	One of the most common substances in the earth's crust. It is found in air, soil and water, and is present in all foods.	Used in coatings to prevent rust, in batteries and in metal alloys. Zn compounds are widely used in industry to make paint, rubber, dyes, wood preservatives and ointments.	Exposure to high levels can occur through eating contaminated food, drinking contaminated water and breathing air contaminated by industries such as smelting, galvanising and car repair garages. Low levels of Zn are essential for good health. Exposure to large amounts can be harmful and can cause stomach cramps, anaemia, and changes in cholesterol levels.

*Adapted from Auckland City Council. Urban Soils Review: Contaminants (http://www.aucklandcity.govt.nz/council/documents/soilquality/contaminants.asp#chart)

** Adapted from CCME (2007)

Appendix 2 – Summary information for dairy, maize, sheep/beef, deer and kiwifruit sample sites (2009-2010)

Site*	Sample No.	Year Established	Land Use	Soil Type	NZ Soil Classification (Order Level)	Remark
15	1	1999	Dairy	Rotomahana	Recent	
16	1	1999	Dairy	Horomanga Sand	Pumice	
17	1	1999	Dairy	Galatea sand	Pumice	
18	1	1999	Dairy	Oropi loamy coarse sand	Pumice	
18	2	1999	Dairy	Oropi hill soils	Pumice	
18	3	1999	Dairy	Kawhatiwhati Sand	Pumice	
19	1	1999	Dairy	Opouriao fine sandy loam	Recent	
29	1	2000	Dairy	Kāingaroa gravelly sand	Pumice	
29	2	2000	Dairy	Kāingaroa gravelly sand	Pumice	
31	2	2000	Dairy	Opouriao fine sandy loam	Recent	
33	1	2000	Dairy	Otara silt loam	Recent	
49	1	2000	Dairy	Oturoa loam	Allophanic	
49	2	2000	Dairy	Oturoa loam	Allophanic	
50	1	2000	Dairy	Oturoa loam	Allophanic	
53	1	2000	Dairy	Katikati sandy Loam	Allophanic	
57	1	2000	Dairy	Paroa silt loam on peat	Gley	
58	1	2000	Dairy	Paroa silt loam on peat	Gley	
59	1	2000	Dairy	Paroa silt loam on peat	Gley	
63	1	2000	Dairy	Katikati sandy Loam	Allophanic	
34	1	2000	Maize	Opouriao fine sandy loam	Recent	
39	1	2000	Maize	Pongakawa sandy loam	Gley	
41	1	2000	Maize	Awakaponga silt loam	Recent	
46	1	2000	Maize	Otara silt loam	Recent	
65	1	2001	Maize	Paroa sandy Loam	Recent	
66	1	2009	Maize	Te Puke sandy Loam	Allophanic	New site
67	1	2009	Maize	Te Puke sandy Loam	Allophanic	New site
68	1	2009	Maize	Katikati sandy Loam	Allophanic	New site

Site*	Sample No.	Year Established	Land Use	Soil Type	NZ Soil Classification (Order Level)	Remark
69	1	2009	Maize	Katikati sandy Loam	Allophanic	New site
70	1	2009	Maize	Parton gritty sandy loam	Organic	New site
71	1	2009	Maize	Parton gritty loamy peat	Organic	New site
45	1	2000	Sheep/beef	Opotiki hill soils	Allophanic	
35	2	2000	Sheep/beef	Kāingaroa gravelly sand	Pumice	
52	2	2000	Sheep/beef	Rotomahana Mud	Recent	
52	3	2000	Sheep/beef	Ōkaro steepland soils	Recent	
51	2	2000	Sheep/beef	Waiowhiro sandy loam	Pumice	
20	2	1999	Sheep/beef	Ohinepanea loamy coarse sand	Pumice	
20	3	1999	Sheep/beef	Ohinepanea hill soils	Pumice	
55	1	2000	Sheep/beef	Oropi loamy sand	Pumice	
47	1	2000	Sheep/beef	Whakamarama sandy loam	Podzol	
62	1	2000	Sheep/beef	Katikati sandy Loam	Allophanic	Not sampled in 2010
35	1	2000	Deer	Kāingaroa gravelly sand	Pumice	
56	1	2000	Deer	Manawahe hill soil	Pumice	
54	1	2000	Deer	Paengaroa sandy loam	Pumice	
60	1	2000	Deer	Katikati sandy loam	Allophanic	Not sampled in 2010
32	1	2000	Kiwifruit	Opotiki sandy Loam	Pumice	
31	1	2000	Kiwifruit	Opouriao fine sandy loam	Recent	
41	2	2000	Kiwifruit	Awakaponga silt loam	Recent	
37	1	2000	Kiwifruit	Paengaroa loamy sand	Pumice	
61	1	2000	Kiwifruit	Katikati sandy Loam	Allophanic	

*For location of sample sites, please refer to Figure 1.

Appendix 3 – Tiered fertiliser management strategy for cadmium (MAF 2011; Tikkisetty 2011)

Tier	Trigger Values and Management Strategy
1	Cadmium exists at the naturally occurring baseline level of 0.6 mg/kg of soil. There is no limit to the application of phosphate fertilisers other than a five-yearly screening soil test for cadmium.
2	Cadmium exists between 0.6 and 1.0 mg/kg of soil. Application rates are restricted to a set of products to minimise accumulation, and landholders are required to test for cadmium every five years
3	Cadmium exists at the level of between 1.0 and 1.4 mg/kg soil. Application rates are further restricted by use of a cadmium programme to ensure that cadmium does not exceed an acceptable threshold within the next 100 years.
4	Cadmium exists at the level of between 1.4 and 1.8 mg/kg of soil. No further accumulation beyond 1.8 mg/kg of soil is allowed. Any further build-up may lead to restrictions on land use.