TEMPORAL CHANGES IN TOPSOIL TRACE ELEMENT CONCENTRATIONS IN THE BAY OF PLENTY

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Abstract
Trace element sampling has recently been included in the Bay of Plenty's regular regional soil quality monitoring programme due to the 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. Archived samples from previous samplings (since 1999) were also included in order to show trends over time. The samples represented five land uses namely dairy, maize, sheep/beef, deer and kiwifruit.

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 appear to be increasing but the increases were not statistically significant due to the small sample size. Nevertheless, this will most likely pose a concern particularly for copper which is now a widely used spray to control the *Pseudomonas* disease (Psa) of kiwifruit vines.

Introduction
Trace element sampling has recently been included in the Bay of Plenty's regular regional soil quality monitoring programme due to the potential risk of accumulation associated with some past and present-day land use practices such as fertilizer application and disease control (e.g., cadmium is an unavoidable contaminant in phosphate fertilizers, facial eczema treatment contains high levels of zinc, and copper is used as a fungicide in orchards). This report discusses the temporal changes of trace element concentrations in farmed topsoils covering dairy pasture, maize, drystock (sheep/beef and deer) pastures and kiwifruit orchards over a ten-year period (1999/2000 to 2009/2010).

Methods
Topsoil samples (0-10 cm) were collected from the regional soil quality sampling sites in 2009 and 2010 (Figure 1). In 2009, dairy pasture and maize cropping sites were sampled. In 2010, sheep/beef pasture, deer pasture, and kiwifruit orchard sites were sampled. The sampling procedure for trace elements followed the standard protocol for NZ soil quality sampling for chemical analysis (Hill and Sparling 2009). The samples were submitted to Hill Laboratories for the analysis of the trace metals arsenic, cadmium, chromium, copper, chromium, lead, mercury, nickel, uranium, and zinc. The concentrations were reported as total

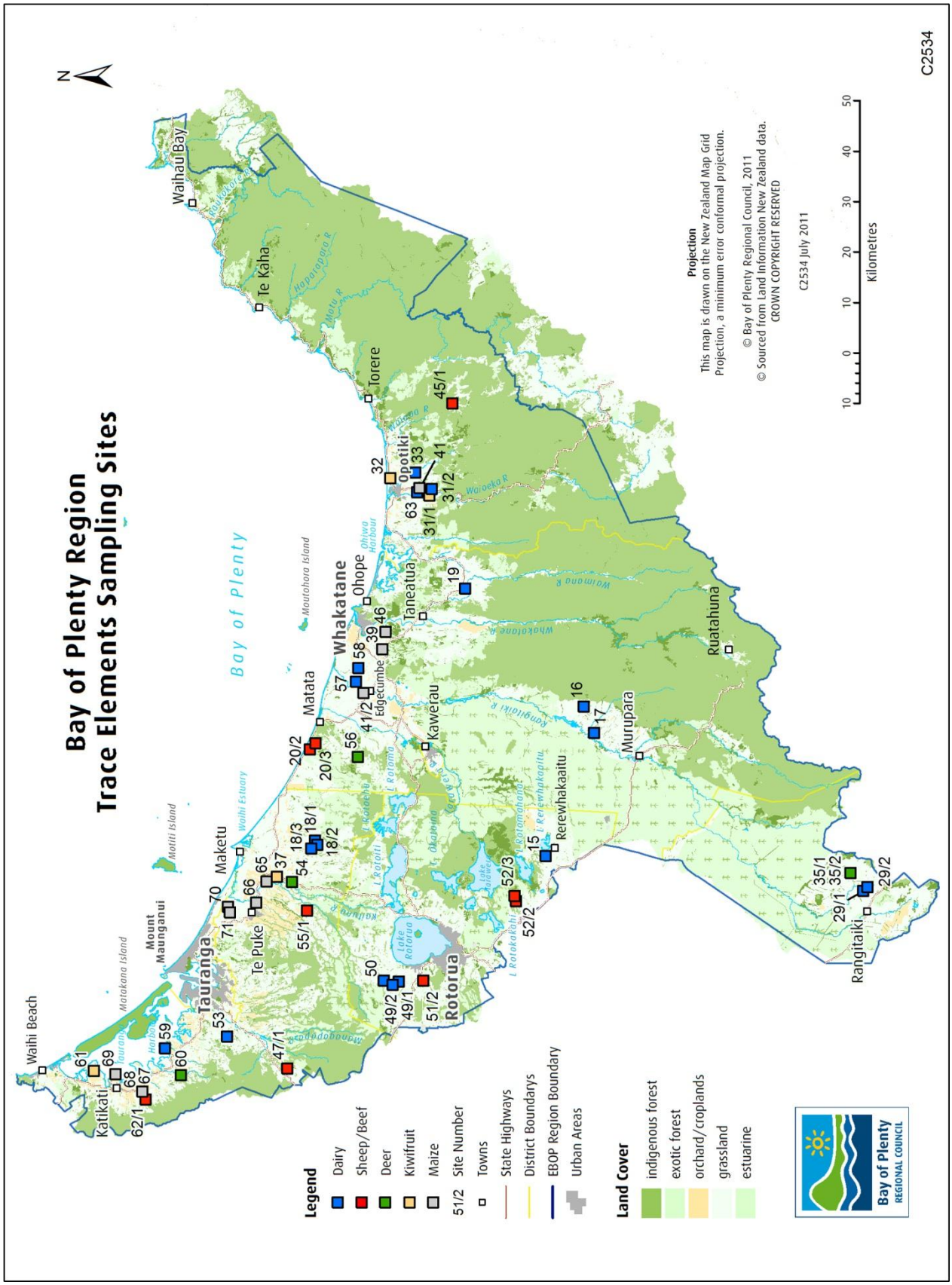

Figure 1. Trace element sampling sites by land use.

recoverable metals in mg/kg dry soil (Kim and Taylor 2009). Mean trace element concentrations by land use class were compared with New Zealand environmental guideline values for biosolid application to soils (NZWWA 2003) except for 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).

Results and Discussion

Dairy pasture sites

Table 1 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 and 2009 were almost identical suggesting that cadmium concentration has not increased since 2004.

Table 1. Changes in topsoil trace element concentrations [mg/kg (± SE)] 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

Maize cropping sites

Mean values for each sampling year were all below the environmental guideline value for each element (Table 2). 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.

Table 2. Changes in topsoil trace element concentrations [mg/kg (± SE)] of maize cropping 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

Sheep/beef sites

Table 3 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 3. Changes in topsoil trace element concentrations [mg/kg (± SE)] 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

Deer pasture sites

Table 4 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.

Table 4. Changes in topsoil trace element concentrations [mg/kg (± SE)] 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

Kiwifruit orchard sites

Table 5 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 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 and this could be a result of the small sample size (n=6 or 5). Nevertheless, this is a concern particularly for copper which is now a widely used spray to control the pseudomonas disease (Psa) of kiwifruit vines.

Table 5. Changes in topsoil trace element concentrations [mg/kg (± SE)] 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

Conclusion

Temporal changes in 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. In kiwifruit orchard sites, copper and zinc concentrations appear to be increasing but the increases were not significant due to small sample size. The increases will most likely pose a concern in the future particularly for copper – now a widely used spray for Psa disease.

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