Results of an initial survey of the leaching from treated posts in vineyards in the Marlborough region

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Results of an initial survey of the leaching from treated posts in vineyards in the Marlborough region.

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Executive summary

- The Marlborough District Council commissioned HortResearch to conduct a general survey to determine the extent of any Copper-Chromium-Arsenic (CCA) leaching from treated posts in Marlborough vineyards. This survey is indicative and does not encompass the complete range of soil types of the entire region. Impetus for this survey came from the detection of arsenic in certain groundwaters in Marlborough. This raised issues in relation to the role of CCA posts, *vis-à-vis* naturally occurring arsenic.

- International work on the use of CCA treated posts in agricultural systems has shown that, over time, CCA leaches into the surrounding soil.

- We have found that CCA is leaching out of treated timber posts in the Marlborough Region. Soils surrounding these posts exceed, in some cases, the recommended guidelines for chromium and arsenic in agricultural soils as set out in the Australian National Environment Protection Council's "Guidelines on the Investigation Levels for Soil and Groundwater" (1999). Some 25% of the samples exceeded guideline levels in the soil for arsenic of 100 mg/kg, and 10% exceeded levels for chromium of 100 mg/kg.

- Evidence from overseas studies indicates that the risk to human health from CCA-contaminated soil is small. No cases of morbidity or mortality have been reported.

- At one site of coarse soil overlying shallow groundwater, we found a significant positive correlation between post age and CCA-leaching. However, there was no significant age correlation in this general survey across other sites. From our general survey, we could not detect any relationship with soil type.

- Previous studies have shown that plant-uptake of CCA is low.

- The survey did not investigate arsenic levels in groundwater. Where posts are intermittently dipping into fluctuating ground water during part of the year, there may be a risk of arsenic leaching into groundwater. However, more work needs to be done to quantify this possibility. Our general survey could not determine the contributory role of CCA posts in relations to the levels of arsenic found in the groundwater.

- The CCA issue could be eliminated by using alternative posts, such as steel, concrete, or untreated woods such as *Eucalyptus* or beech. Alternatively, CCA-treated posts could for example, be lacquered, or otherwise protected, to reduce the rate of CCA leaching.

Introduction

CCA in vineyards of the Marlborough region

Recently, concern has been expressed over the possibility of Copper Chromium Arsenic (CCA) timber treatment leaching from treated posts across the 10,000 ha of vineyards throughout the Marlborough region (Bourne, 2003). Recently, elevated levels or arsenic have been reported in certain groundwaters in Marlborough. The role of CCA-treated posts, *vis-à-vis* naturally occurring arsenic, has been questioned.

Most vineyard posts are given an "H4" treatment that protects pine against decay when in contact with soil, or water. This results in a wood concentration of copper, chromium and arsenic of 1730, 3040, 2710 mg/kg respectively on a dry matter basis. Given a density of 579 posts per hectare, and an average post weight of 12 kg, each hectare of vineyard has a CCA loading of 12, 21 and 17 kg respectively. Anecdotal evidence indicates that the posts are replaced at a rate of 4% per year, indicating that if leaching from posts occurs, soil CCA contamination will be cumulative, given the general immobility of CCA in the soil. Copper is the most immobile component, followed by arsenic and dichromate (Carey *et al.*, 1996a). However, dichromate [Cr(VI)] is rapidly reduced to Cr(III), which is less mobile and less toxic.

In the Australian National Environment Protection Council's (NEPC) "Guidelines on the Investigation Levels for Soil and Groundwater" (1999, Table 5-A), the Health Investigation Levels (HIL) in residential soil with garden access for arsenic is 100 mg/kg, for chromium it is also 100 mg/kg, and for copper it is 1000 mg/kg. We take these levels as our guideline values. Lower values are given by the NEPC for Ecological Investigation Levels (EIL) and these are respectively 20, 1 and 100 mg/kg. In the soil acceptance criteria of the NZ "Health and Environmental Guidelines for Selected Timber Treatment Chemicals" (MfE, 1997, Table 5.17), the interim value for arsenic in agricultural soils is 30 mg/kg, plus 4 mg/kg for chromium and 40 mg/kg for copper.

CCA leaching from treated posts

There is evidence from several studies that CCA leaches out of treated timber into surrounding soil (Stilwell and Graetz, 2001; Schultz *et al.*, 2002; Chirenje *et al.*, 2003; Zagury *et al.*, 2003) or water (Archer and Preston, 1994; Hingston *et al.*, 2001). Schultz *et al.* (2003) showed that after 5-6 years, 24% of the CCA treatment in stakes of Southern Yellow Pine had leached into the surrounding soil. Zagury *et al.* (2003) found soil CCA concentrations adjacent to treated posts up to 1460, 287 and 410 mg/kg respectively. After 85 months of exposure in the marine environment, 50% of Cu had leached from pine timber (Archer and Preston, 1994)

In the United States, the use and disposal of CCA-treated timber has resulted in large amounts of arsenic in many residential soils, as well as landfills used for disposal of treated wood (Bleiwas, 2000). According to the US Environmental Protection Agency (EPA) "The amount and rate at which arsenic leaches, however, varies considerably depending on numerous factors, such as local climate, acidity of rain and soil, age of the wood product, and how much CCA was applied." (US EPA, 2002). Soil conditions, especially pH, organic matter and clay contents, play an important role in leaching and movement of CCA (Carey *et al.*, 1996b; Hingston *et al.*, 2001). Zagury *et al.* (2003) showed soil contaminant levels were more strongly correlated with soil type, rather than the age of pole.

Studies on treated posts have shown that soil CCA concentrations decreased rapidly with increasing distance from the post (Zagury *et al.*, 2003), especially for copper and chromium, whereas arsenic is more mobile. Copper and chromium concentrations approached background levels at a distance of 50 mm from the post. Arsenic has been found at a distance of 500 mm from posts, and at depths of 1 m below the posts (Zagury *et al.,* 2003). Allinson *et al.* (2000) reported that once in soil, the copper component of CCA is arrested by exchange with the soil, even in sandy soils. An absence of CCA in soil surrounding treated posts does not necessarily indicate that CCA is not coming out of the post. The absence of metals may be due to prior leaching.

End-grain penetration of CCA into wood is 40 times greater than lateral penetration, and in reverse, may greatly influence the leaching rate back out (Morgan and Purs-Low, 1973). Archer and Preston (1994) demonstrated this by showing that leaching was 40 times greater out of the end of the post. This would indicate that the greatest soil CCA concentrations should be found under the post. The release of CCA from the bottom of the post would also increase the likelihood of direct movement to groundwater, since there would be less soil to retard the downward mobility of CCA. In some locales, the bottom of the post may even be periodically immersed in groundwater. If the post is dipping intermittently into groundwater, then lateral convective flow between the wood and the soil could greatly increase any CCA leaching (Hingston *et al.*, 2001).

Potential problems arising from CCA leaching from treated posts

The leaching of CCA from treated posts into soil is of concern because, depending on its extent, it may reduce soil fertility, contaminate groundwater, and present a hazard if land use changes occur. If copper, chromium and arsenic are released from treated posts, they will tend to remain in the soil for a long time. All three elements are found naturally in New Zealand soils, usually at low concentrations. For example, arsenic concentrations in uncontaminated soils seldom exceed 10 mg/kg (Adriano, 2001) and its abundance in the Earth’s crust is only 1.8 mg/kg (Mason and Moore, 1982). Arsenic can occur naturally at elevated levels in ground and surface waters in New Zealand. This is so-called geogenic arsenic (Robinson *et al.*, 2003). The elevated levels of arsenic in Marlborough groundwater may be of geogenic origins. The role of CCA-treated posts is unknown.

Chromium is an essential micronutrient for animals, while copper is essential for both plants and animals (Salisbury and Ross, 1992). Arsenic is a non-essential element. At elevated concentrations, all three elements are toxic (McLaren and Cameron, 1996).

Past and present pesticide use can contribute to copper and arsenic in vineyard soils. Copper-based fungicides are used commonly on vineyards. Historically, arsenic-based pesticides were used extensively to control insect pests on orchards, and as a biocide in sheep dips.

In soil, arsenic is the most bio-available of the three elements, but unfortunately it is also the most toxic to humans (Read, 2003). Nonetheless, Belluck *et al.* (2003)

reported that there have been no cases of morbidity or mortality from exposure to either anthropogenic or natural elevated soil arsenic levels. It is, however, a concern in groundwaters worldwide.

In general, the accumulation of As in the edible parts of most plants is low (O'Neill, 1995). Table 1 details reported effects of soil arsenic contamination on plant growth.

In the Marlborough Region, negative effects could occur if significant amounts of CCA were leaching from vineyard posts. These include:

- Contamination of groundwater.
- Soil accumulation of CCA to exceed guideline levels.

Table 1. Reported effects of soil arsenic contamination on plant growth (from Mahimairaja *et al.*, 2004)

Arsenic Concentration (mg/kg)	Effect	Reference
360	Yield reduction in barley; plants showed symptoms of As toxicity and P deficiency	Lambkin and Alloway (2003)
50 – 100	Reduction in growth of vegetative and root system in Tomatoes	Miteva (2002)
70 – 100	As contents in rice cultivars exceeded the WHO standard	Xie and Huang (1998)
0, 15, 20, 30, 50 and 100 as power station fly ash or disodium hydrogen arsenate.	50% yield reduction in wheat, barley and oats. Sensitivity to As was in the order: oats > wheat > barley.	Toth and Hruskovicova (1977)
100	Decreased the height of the apple tree: 100% growth inhibition at above 100 mg/kg.	Benson (1976)
0-280 kg As ha^{-1} (Fine sandy loam soil) 0-560 kg As ha^{-1} (Clay soil).	Significant growth reduction in cotton and soyabean.	Deuel and Swoboda (1972)
NaAsO$_2$ applied at rates up to 720 kg As ha^{-1}	As toxicity persisted for four growing seasons in potatoes and peas.	Stevens *et al*. (1972)

Project goals

A general survey was undertaken by HortResearch, under contract to the Marlborough District Council, to determine the extent of any leaching from CCA-treated posts in

Marlborough vineyards. Particular emphasis was given to vineyards in the Rarangi region where the groundwater level periodically rises above the bottom of the posts. These soils are typically sandy gravels with low organic matter content. Such conditions have been shown in previous studies to result in the greatest rate of CCA leaching from posts. A range of post ages and soil types were also considered.

Materials and methods

Sampling locations and protocols

Table 2. Description of posts sampled at each vineyard. For each location and post type, three replicates were chosen

Number	Soil type	Year of post installation	Type of post
1	Shallow and loamy silt loam	1988 1999	Half rounds Quarter rounds
2	Loamy and sandy alluvium	2001	Half rounds
3	Deep silt loam	1983	Full rounds
4	Clay loam	2002	Half rounds
5	Deep silt loam (poorly drained)	2001	Quarter rounds
6	Very shallow silt loam overlaying gravel. Shallow groundwater	(X) 2000 (Y) 2001 (Z) 2003 (July)	Half rounds Half rounds Half rounds

In conjunction with the Marlborough Council, six sites (Appendix 1) were selected to represent a range of post ages and soil types from around the Marlborough Region (Table 1). Three classes of posts were sampled from the shallow groundwater areas for reasons already outlined. At all sites except (4), the posts were levered out of the ground for sampling. Care was taken to cause minimal soil disturbance around each post. At site (4), the small vines and stone-free soil allowed the posts to be dug out using a spade. For each class of posts, three replicates were taken.

Five soil samples of at least 200 g dry weight, and two wood samples were taken around each post (Fig. 1). Soils samples adjacent to the post, (A), and at 50 mm horizontal distance, (B), were collected by scraping soil from the side of the post-hole using a 440 mL steel can. Soil samples beneath the post, (samples C and D), were collected using a soil auger. As a reference, soil from the inter-row, (E), was collected after the surface litter and any vegetation was removed. At site 6 (X and Y) an additional sample was taken between the rows to determine the effect that drip irrigation might have had on the soil metal concentrations. Subsequently, we found there were no significant differences between the samples underneath the vines, and those taken from between the rows, so only the former are reported here.

Approximately 20 g (dry weight) samples of wood were removed from both the above- and below-ground portions of the post using a chisel. For the half-round and quarter-round posts, wood was removed to approximately 15 mm deep at the intersection between the flat face and the circumference. An additional six samples were taken from new posts at site (2).

Chemical and biological analyses

The samples were sent to a commercial laboratory (Hill Laboratories, Hamilton) for dry-weight determinations of copper, chromium, arsenic and boron. To assess any impact on soil health, soil microbiological activity was determined at HortResearch using a dehydrogenase assay following the method of Chandler and Brookes (1991). This assay determines the concentration of triphenylformazan (TPF), which can be used as a guide to soil health. In heavy-metal contaminated soils, TPF values tend to be low due to metal toxicity.

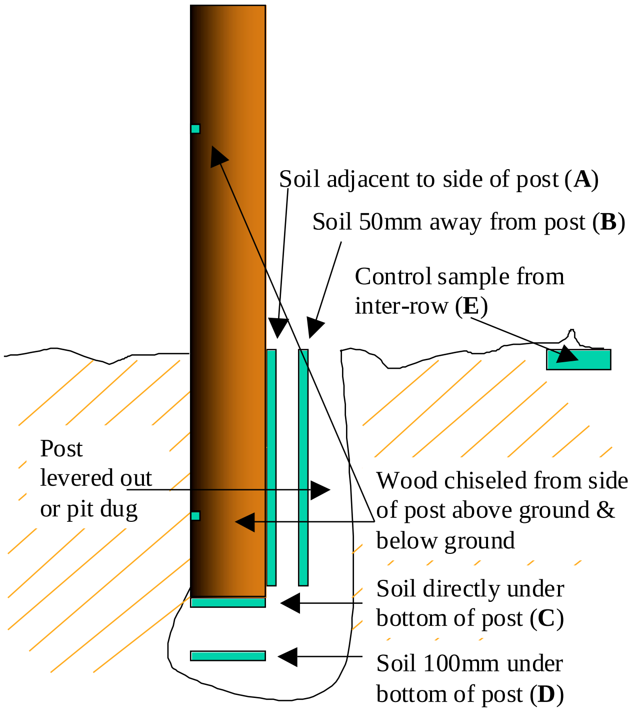

Figure 1 Locations of soil and wood samples taken from around each post

Statistical analyses

All statistical analyses were performed using MINITAB. Means were compared using an analysis-of-variance technique, ANOVA, and significant differences were determined using Fisher’s Test, with a 95% confidence interval.

Results and discussion

General overview of CCA leaching from vineyard posts in Marlborough

Fig. 2(I) shows the average CCA concentrations in the control soil, and soils surrounding the treated posts. Data are presented for all the posts tested. In each case, the soils surrounding the posts had significantly higher CCA concentrations, (A to D), than the control soil (E). Soil directly beneath the posts (C) had the highest CCA concentration, followed by soil immediately adjacent (A). The concentrations in soil at 50 mm from the side of the post (B), and at 100 mm beneath the post (D), were significantly lower than those in soil directly adjacent to the post. These concentrations were still significantly higher than the controls. The average soil CCA concentrations in our study are generally consistent with the findings of overseas studies (Hingston *et al.*, 2001; Chirenje *et al.*, 2003; Zagury *et al.*, 2003).

Fig. 2(II) shows the CCA concentrations in new posts, and the average of all the aboveground and belowground samples that were taken from posts of various ages. The belowground samples in the wood were significantly lower than the aboveground samples in the wood, and the new post levels. Fig. 2(II) confirms that CCA is leaching out of vineyard posts into the soil. However, there were no significant differences between the new posts and the aboveground samples. Leaching from the aboveground portions appears minimal.

Soil samples from several sites contained more than 100 mg/kg As. This level is the threshold set by the Australian National Environmental Protection Council (NEPC), for residential soils with garden access. Across all sites, 25% of the samples were above the NEPC guidelines for arsenic, and 10% of the samples were above NEPC guidelines for chromium (100 mg/kg). None of the copper values exceeded the NEPC guidelines of 1000 mg/kg. However, 33 samples were above 200 mg/kg, a level we have shown to cause plant toxicity in other studies (Thayalakumaran *et al.*, 2003).

The amount of CCA that leaches from vineyard posts will be dependent on a range of variables such as soil type, climate, irrigation regime, and fertiliser regime. Therefore, when considering the relationship between one variable and CCA leaching, no significant correlation might be found from a general survey, such as ours, because of the confounding influence of other variables. In our regional study, across all sites tested, there was no significant correlation between post age, and the CCA concentration in the surrounding soil. Nevertheless, a significant positive correlation between post age and soil CCA concentration was found on one single soil type, namely Site (6) (Fig. 3). This seems to relate specifically to the conditions at Site (6), which would merit closer scrutiny, as it is possibly due to the shallow groundwater. We will discuss this further later on.

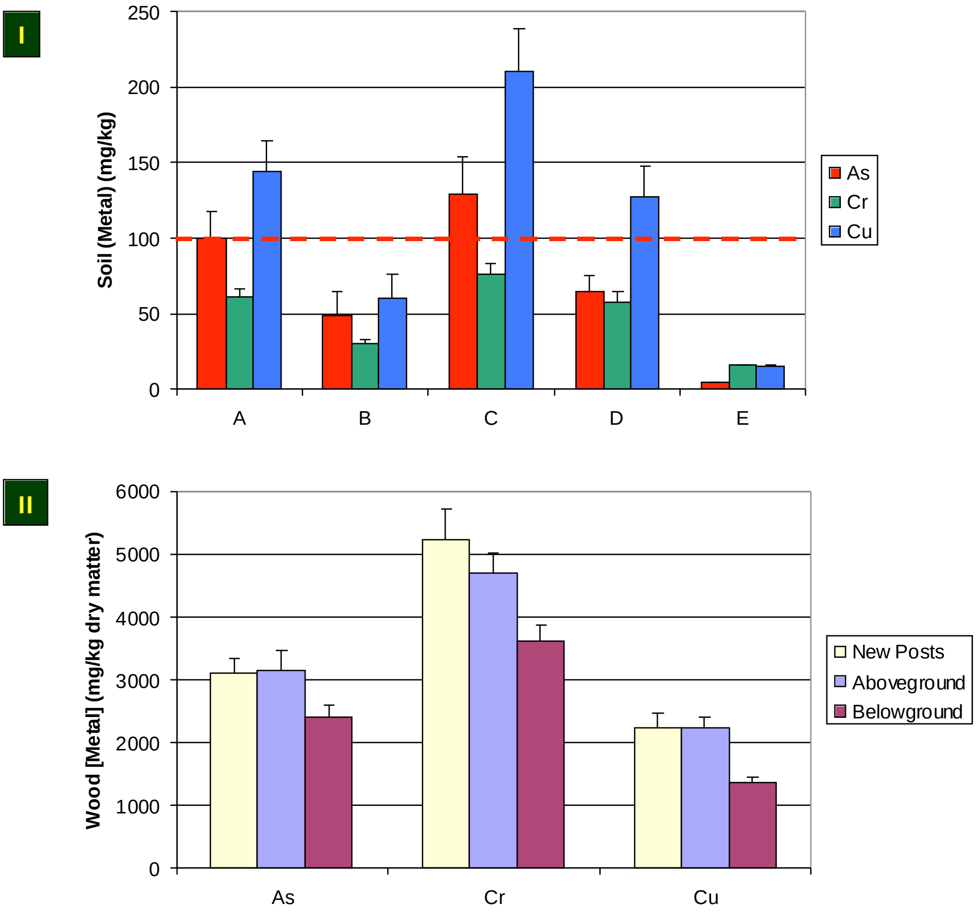

Figure 2 Average soil (I) and wood (II) CCA concentrations across all sites sampled. "Aboveground" and "Belowground" refer to post wood sampled aboveground and belowground respectively. The locations of samples 'A' to 'E' are shown in Figure 1. Bars represent the standard error of the mean (n=27 for all means except 'New Posts' where n=6). The red dashed line is the NEPC guideline for arsenic in soil.

Zagury *et al.* (2003) showed that soil contamination levels were more strongly correlated with soil type, rather than pole age. They found that more leaching occurred in low-organic matter and low-clay content soils. It is interesting to note that at our Site (4) with a high clay content clay-loam, we also found had the lowest soil CCA concentrations (Fig. 5). This is consistent with the findings of Zagury *et al.* (2003) because it seems that at Site (4) less CCA had leached into the high clay-content soil there.

Of all the treatment chemicals, copper occurred at the greatest concentration in the soil, despite having the lowest concentration in the post. Arsenic was second, followed by chromium. However, the higher soil copper concentration does not necessarily indicate that more copper is leaching out of the posts relative to the other CCA components. It probably reflects the immobility of copper in the soil. The other components, especially arsenic, may have already leached through the soil, therefore presenting a lower concentration adjacent to the post in our measurements.

CCA leaching in shallow-groundwater areas (Site 6)

Fig. 3 (I-III) shows the CCA concentrations in soils surrounding posts at Site (6). The distribution of CCA around the post here is similar to all the posts sampled elsewhere (Fig. 2I), with the highest CCA concentrations occurring beneath the post. At Site (6), three ages of posts were selected on the same soil type. The soil CCA concentrations show an increase with post age in the ground. This is consistent with the hypothesis that CCA is leaching out of the posts over time. It is interesting to note that at Site (6), there is less lateral movement of CCA than at the other sites. At 50 mm away from the post (B) the CCA levels are reduced, although still significantly greater than the controls (E). However, there is a larger vertical movement in this coarse-textured permeable soil of low organic matter. At 100 mm beneath the posts, arsenic levels are approaching the NEPC limit of 100 mg/kg.

Fig. 3 also shows a significant difference in the soil CCA concentrations between the years over which the posts have been in the ground, namely the 2000 and 2001 posts. This indicates that CCA leaching is still occurring some three years after the posts were installed.

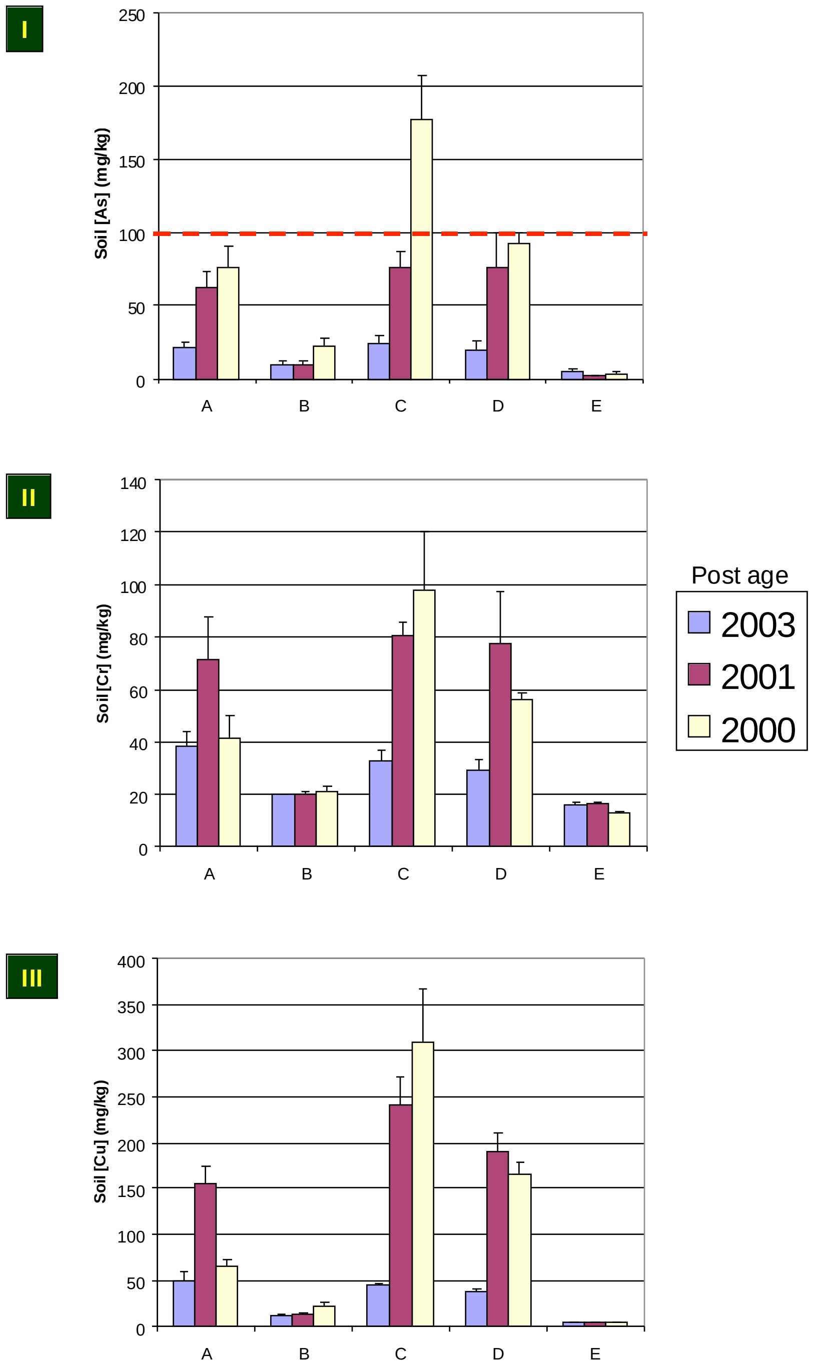

Figure 3. Soil arsenic (I), chromium (II) and copper (III) from vineyard posts at Site (6), a shallow groundwater area. The locations of 'A' to 'E' are shown in Figure 1. Bars represent the standard error of the mean (n=3). The red dashed line is the NEPC guideline for arsenic in soil.

Fig. 4 shows the CCA concentrations in the wood of the posts from vineyards at Site (6). Older posts show higher concentrations in the aboveground portions, compared to the belowground portions, which is indicative of leaching from the parts of the posts in the soil. However, it is not possible to make clear quantitative estimates of the amount of CCA that has leached from the post, because of the variability in the aboveground CCA concentrations. Also there could be a slight migration of CCA up the post due to continual wetting in the belowground portion, and evaporation from the above ground portion. Thus, over time, the post might act as a wick. Our general survey is not sufficiently refined to determine this, but there is a consistent pattern of loss of CCA from the belowground portion, indicative of sequential loss to the surrounding soil-water system.

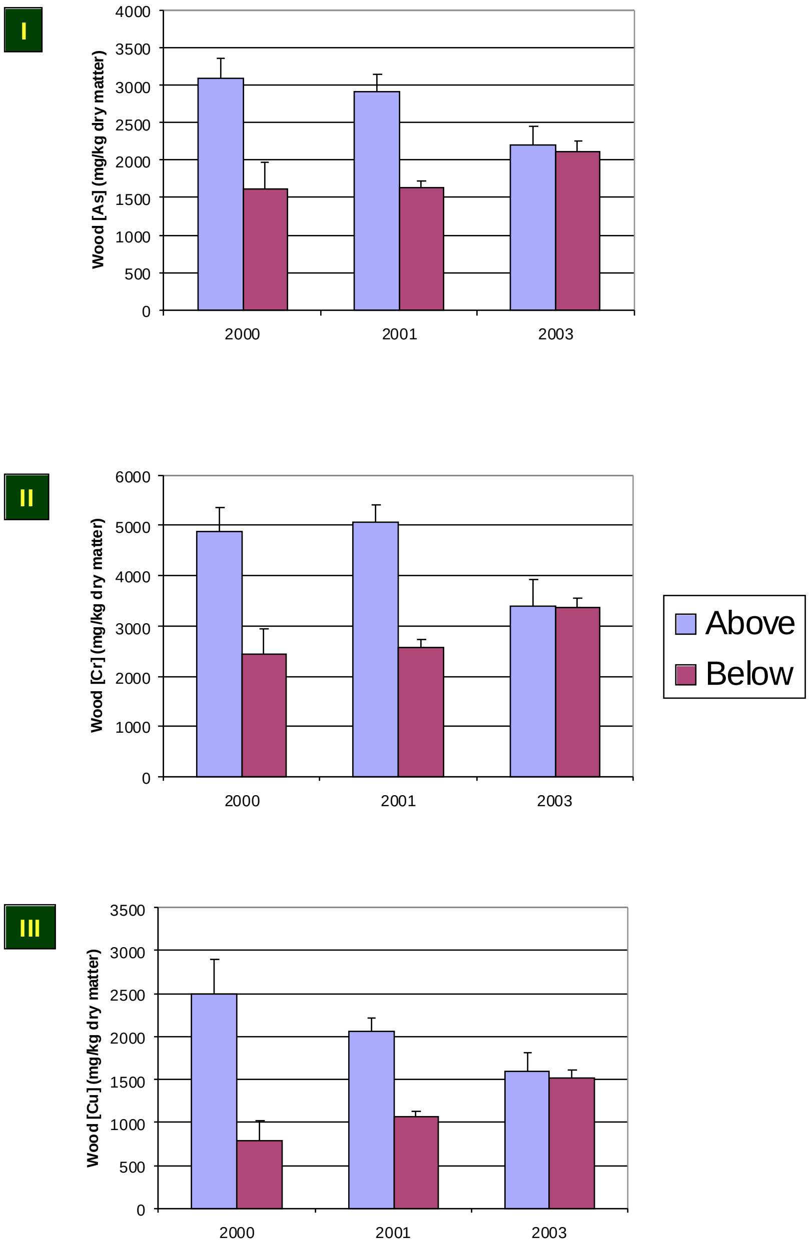

Figure 4 Wood concentrations of arsenic (I), chromium (II) and copper (III) in posts of three ages taken from vineyards at Site (6). "Above" and "Below" refer to aboveground and belowground samples respectively. Bars indicate the standard error of the mean (n=3).

Our soil-based measurements at Rarangi show that we can recover in the soil close to the post, about 65-70% of the arsenic that has leached from the post. So only some 30% of the arsenic appears to be missing, and potentially lost to groundwater. If we increased the zone of sampling around the post, we would most likely recover most of the arsenic in the soil. With time, the arsenic found in soil might still then leach from the soil into groundwater, but because of the longer time-period it would likely be diluted by the new groundwater entering the system, because of rapid transmission in this aquifer system.

CCA leaching from other sites around the Marlborough Region

Figs. 5 (Sites 2 - 5) and 6(I-III) show the CCA concentrations in the soils of the other vineyards tested. Fig. 5 shows that there are considerable differences, between sites, in both the total amounts of copper, chromium and arsenic that have leaked out, as well as the distribution of these elements around the post.

The concentrations of CCA in soils surrounding posts in the loamy sandy alluvium (Site 2) decrease sharply with increasing horizontal distance from the post ('A' *cf.* 'B' in Fig. 5, Site 2). But the CCA concentrations in the soil 100 mm beneath the post were similar to those in contact with the post-end ('C' *cf.* 'D' in Fig. 5, Site 2).

The deep silt-loam soils surrounding the 20-year-old posts at Site (3) have up to 400 mg/kg arsenic, and lesser amounts of chromium and copper. Site (3) was the only vineyard sampled with full-round posts (Table 2). This, combined with the greater age of the posts, may have resulted in more CCA leaching, as compared to other vineyards. Also, the older posts may have probably undergone a different treatment regime. This may lead to greater losses, for whatever unknown reason, due to the formulation differences.

Soils at Site (5) were somewhat similar to those at site (3). However, none of the soils were found to be above the NEPC guidelines for arsenic. This may be attributed to the different leaching characteristics of these quarter-round posts, or more likely, the shorter time the posts have been in the ground.

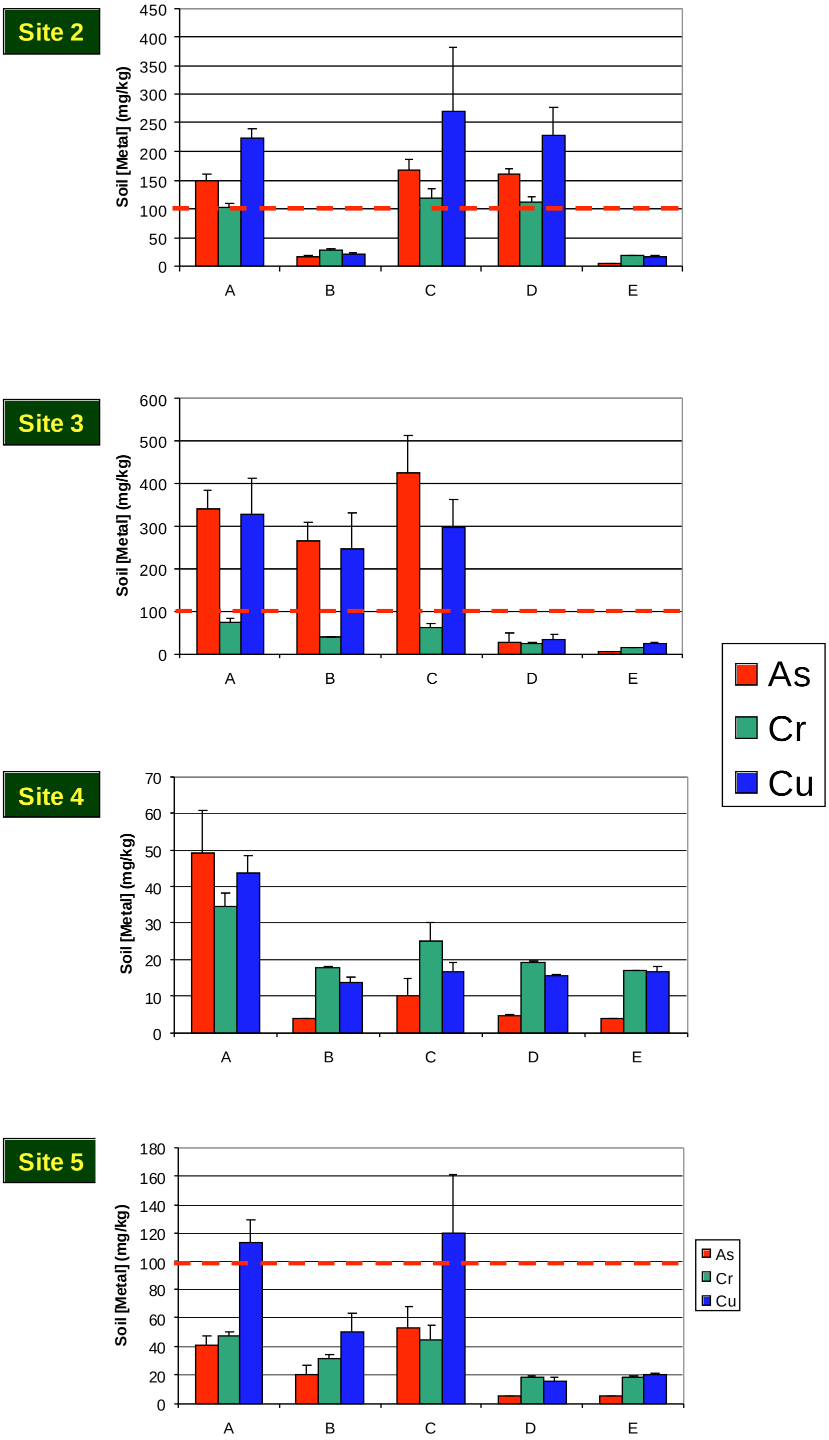

Figure 5. Soil CCA concentrations at various locales throughout the Marlborough Region. The locations of Sites (1-5) are shown in Appendix 1. Bars represent the standard error of the mean (n=3). The red dashed line is the NEPC guideline for arsenic in soil.

Unlike Site (6), the data for Site (1) indicate that the soils surrounding the older posts have lower CCA concentrations. There are several possible explanations for this observation. The initial treatment regimes of the wood may simply have been different. There might be different leaching rates from half-round posts (1988) compared to quarter rounds (1999). The absence of CCA in the surrounding soil may also mean that it could have subsequently leached down form these soil profiles for the older posts. Our general survey would not be able to discriminate between these to assign cause. It is important to note that, when comparing these results with Site (6), the most recent posts sampled at Site (1) were installed in 1999, whereas the oldest posts at Site (6) were only installed in 2000. Therefore we are comparing posts of different ages and further details would be required to assess the causes.

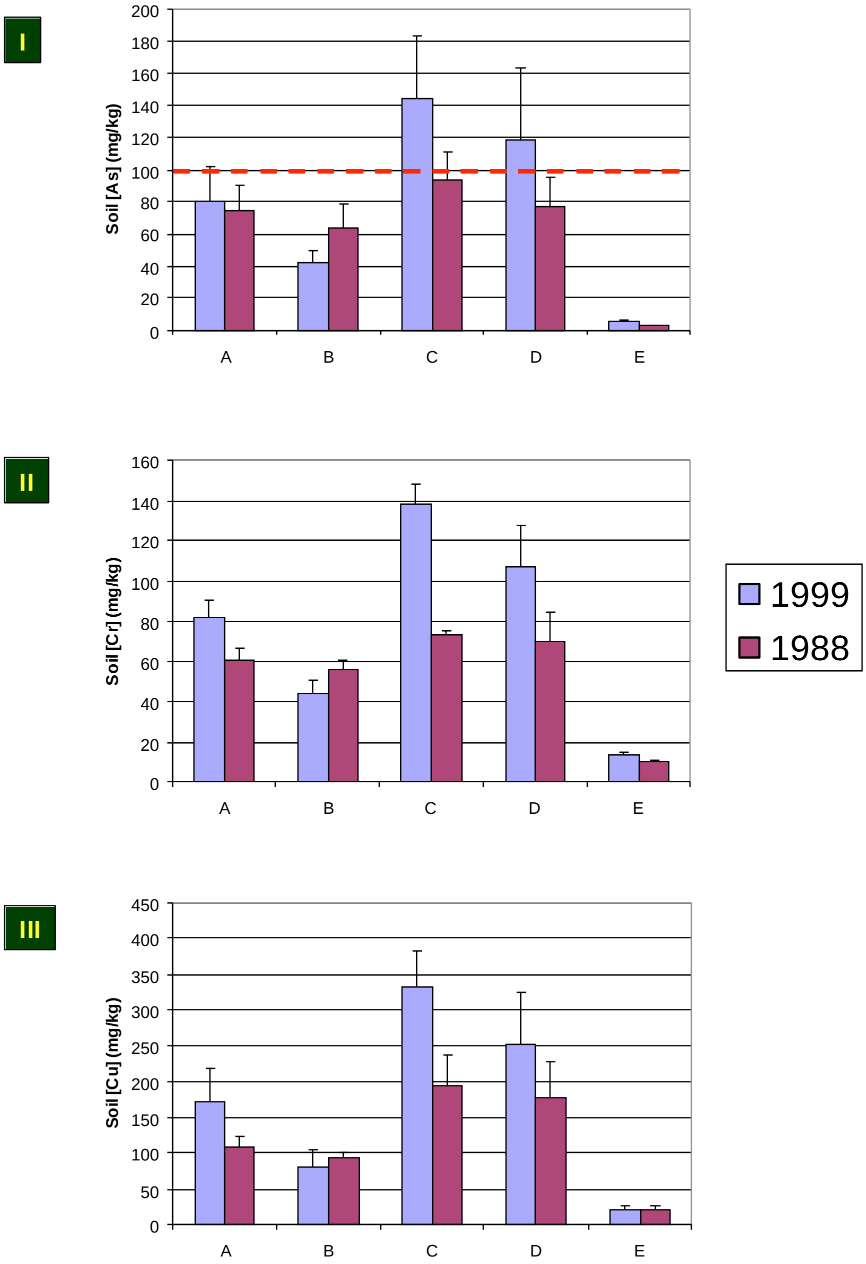

Figure 6. Soil arsenic (I), chromium (II) and copper (III) from Site 1 vineyard posts of different ages. Bars represent the standard error of the mean (n=3). The red dashed line is the NEPC guideline for arsenic in soil.

Boron leaching from treated posts

The boron concentrations in all the soils and posts tested were below detection limits (20 mg/kg). This indicates that boron leaching from posts does not, in terms of soil build-up, present any hazard in the Marlborough region.

Biological activity in vineyard soils from the Marlborough region

Table 3 shows the average biological activity determined by a dehydrogenase assay, in the vineyard soils sampled in the Marlborough region. Across all sites, as well as at individual sites, there were no significant differences between the sampling regions around the post. The control soil (E) had significantly more biological activity than the soils adjacent to the treated posts. However, due to our sampling protocol, this does not necessarily indicate that CCA is negatively affecting soil microbial activity, because sample (E) was taken just under the soil surface, where biological activity is normally greater. Samples (A-D) were taken deeper, where lesser activity is expected. There were no significant correlations between any of the components of CCA and biological activity. So from our general survey, we cannot, therefore, draw any conclusions as to the effect of soil CCA on soil microbial activity. A tailored sampling protocol could be developed to determine this.

Table 3. Average dehydrogenase activity measured as triphenylformazan (TPF) concentration from vineyard soils in the Marlborough Region (n=27)

	TPF (mg/kg)	Standard error
A (adjacent)	1.26	0.2
B (50 mm away)	0.99	0.16
C (directly underneath)	0.90	0.14
D (100 mm below)	0.75	0.14
E (control)	2.07	0.23

Impacts from chemical leaching from treated posts in vineyards in the Marlborough region.

The Marlborough region, excluding shallow-groundwater areas

The results from our general survey indicate that CCA does leach from treated posts over time. As the average post life is expected to be 25 years, and around 4% of the posts are replaced annually, the use of treated posts could lead to a gradual accumulation of CCA in the soil, as well as the possible movement of arsenic away from the posts. CCA levels might eventually accumulate locally around the post to the point where they could have impacts. The rate of accumulation over significant soil volumes across the vineyard is likely to be low. Our survey focused on newer posts, and did not measure soil around posts that had been replaced. In the future, measurement of CCA in soils surrounding replacement posts in older vineyards, would enhance our understanding of long-term CCA accumulation and leaching processes.

For soils where groundwater does not come into contact with the posts, there seems a low exposure risk posed by the use of CCA treated timber. Previous studies (O'Neill, 1995) indicate that uptake of CCA into the grapes is unlikely, however, experiments should be conducted to discount this possibility.

Shallow-groundwater areas

The possibility of chemicals reaching groundwater from treated posts at Site (6) cannot be discounted. This study has shown that CCA-leaching from posts has occurred in a three-year period. Previous overseas studies (Hingston *et al.,* 2001) have shown that the contact of posts with groundwater greatly increases leaching. Further testing is warranted to determine the fate of arsenic leaching from CCA-treated posts at Site (6). This could include measuring CCA at various distances from the posts, and a determination of the soil's capacity to retard movement and immobilise the CCA in the soil.

Separately, we have begun a controlled study in isolated containers to examine the CCA-exchange processes between soil and a water-table that intermittently wets the bases of posts. As well, a laboratory analysis of the binding strength of the exchange of arsenic with the soil is being carried out. These results will enable a better prediction of arsenic leaching and fate.

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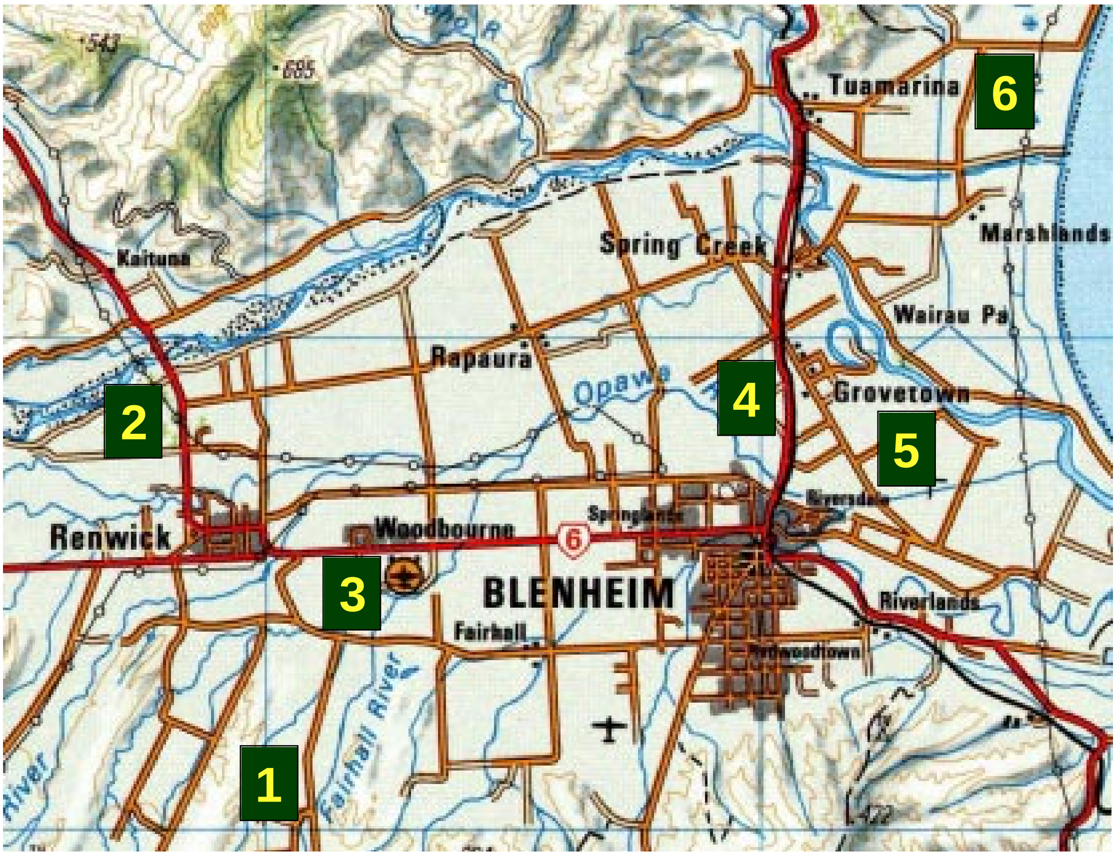
Appendix 1: Sampling locations



Sampling locations around the Marlborough Region. The Table below contains a description of each site.

Description of posts sampled at each vineyard. For each location and post type, three replicates were chosen

Number	Name	Year of post installation	Type of post
1	Brancott	1988	half rounds
		1999	quarter rounds
2	Kaituna	2001	half rounds
3	Renwick	1983	full rounds
4	Rowley	2002	half rounds
5	Lower Wairau	2001	quarter rounds
6	Rarangi		
	(X)	2000	half rounds
	(Y)	2001	half rounds
	(Z)	2003 (July)	half rounds

Appendix 2: Raw data

Appendix. All concentrations in mg/kg on a dry matter basis. Note “1.1” denotes samples taken from between rows. Samples highlighted in red indicate where one or more components were above the NEPC limit of 100 mg/kg for either As or Cr.

		B	As	Cr	Cu	TPF
1	Raupara 1 A	< 20	104	73	272	0.98
2	Raupara 1 B	< 20	8	28	36	0.45
3	Raupara 1 C	< 20	103	100	424	0.96
4	Raupara 1 D	< 20	50	65	225	0.73
5	Raupara 1 E	< 20	4	22	19	2.71
6	Raupara 7 Below	< 20	4080	6340	1940	
7	Raupara 8 Above	< 20	4250	6870	3300	
8	Brancott 1 A	< 20	76	87	260	2.28
9	Brancott 2 A	< 20	119	93	103	1.53
10	Brancott 3 A	< 20	46	64	152	2.13
11	Brancott 4 A	< 20	104	59	108	1.81
12	Brancott 5 A	< 20	67	53	83	1.77
13	Brancott 6 A	< 20	51	71	136	1.61
14	Brancott 1 B	< 20	53	58	118	2.05
15	Brancott 2 B	< 20	46	37	35	1.21
16	Brancott 3 B	< 20	28	37	88	1.56
17	Brancott 4 B	< 20	91	56	86	1.03
18	Brancott 5 B	< 20	61	49	80	1.85
19	Brancott 6 B	< 20	39	63	112	1.51
20	Brancott 1 C	< 20	153	148	431	2.26
21	Brancott 2 C	< 20	207	148	258	2.08
22	Brancott 3 C	< 20	73	118	307	0.79
23	Brancott 4 C	< 20	120	74	142	1.35
24	Brancott 5 C	< 20	99	76	159	0.96
25	Brancott 6 C	< 20	62	70	281	0.31
26	Brancott 1 D	< 20	131	130	383	1.83
27	Brancott 2 D	< 20	190	124	242	1.52
28	Brancott 3 D	< 20	35	67	130	0.59
29	Brancott 4 D	< 20	113	74	161	1.12
30	Brancott 5 D	< 20	57	44	100	0.79
31	Brancott 6 D	< 20	61	92	272	0.65
32	Brancott 1 E	< 20	7	15	31	1.80
33	Brancott 2 E	< 20	3	14	15	3.13
34	Brancott 3 E	< 20	6	11	16	1.66
35	Brancott 4 E	< 20	3	11	22	2.06
36	Brancott 5 E	< 20	3	10	29	2.72
37	Brancott 6 E	< 20	3	10	11	0.92
38	Brancott 1 Above	< 20	2150	4060	1730	
39	Brancott 1 Below	< 20	1250	2190	740	
40	Brancott 2 Above	< 20	1610	3840	1630	
41	Brancott 2 Below	< 20	2420	4180	1490	
42	Brancott 3 Above	< 20	4010	5810	2880	
43	Brancott 3 Below	< 20	2680	4380	1490	
44	Brancott 4 Above	< 20	1880	3800	1460	
45	Brancott 4 Below	< 20	2140	3650	1040	
46	Brancott 5 Above	< 20	4790	7460	2220	
47	Brancott 5 Below	< 20	3650	6120	1310	

48	Brancott 6 Above	< 20	2480	5080	2350	
49	Brancott 6 Below	< 20	2610	5350	1820	
50	Renwick 1 A	< 20	405	89	497	0.54
51	Renwick 2 A	< 20	359	52	269	0.69
52	Renwick 3 A	< 20	260	78	211	0.44
53	Renwick 1 B	< 20	283	40	407	0.75
54	Renwick 2 B	< 20	327	38	208	0.79
55	Renwick 3 B	< 20	191	38	130	0.32
56	Renwick 1 C	< 20	476	78	426	0.43
57	Renwick 2 C	< 20	547	47	250	0.48
58	Renwick 3 C	< 20	254	63	216	0.40
59	Renwick 1 D	< 20	6	20	18	0.31
60	Renwick 2 D	< 20	10	21	17	0.57
61	Renwick 3 D	< 20	69	30	61	0.54
62	Renwick 1 E	< 20	5	16	29	1.33
63	Renwick 2 E	< 20	5	16	28	2.55
64	Renwick 3 E	< 20	4	17	19	0.65
65	Renwick 1 Above	< 20	9360	7980	4900	
66	Renwick 1 Below	< 20	4810	4090	2270	
67	Renwick 2 Above	< 20	3990	3920	2440	
68	Renwick 2 Below	< 20	2090	2180	740	
69	Renwick 3 Above	< 20	2270	2530	1850	
70	Renwick 3 Below	< 20	3150	3250	908	
71	Lower Wairau 1 A	< 20	30	53	107	1.51
72	Lower Wairau 2 A	< 20	41	46	143	1.42
73	Lower Wairau 3 A	< 20	52	42	88	1.26
74	Lower Wairau 1 B	< 20	8	24	25	1.31
75	Lower Wairau 2 B	< 20	22	33	69	1.59
76	Lower Wairau 3 B	< 20	31	36	57	1.71
77	Lower Wairau 1 C	< 20	83	65	202	0.85
78	Lower Wairau 2 C	< 20	33	33	77	0.84
79	Lower Wairau 3 C	< 20	44	36	80	0.89
80	Lower Wairau 1 D	< 20	6	20	20	0.35
81	Lower Wairau 2 D	< 20	4	18	13	0.41
82	Lower Wairau 3 D	< 20	5	17	14	0.53
83	Lower Wairau 1 E	< 20	5	20	17	1.20
84	Lower Wairau 2 E	< 20	5	18	22	2.71
85	Lower Wairau 3 E	< 20	4	18	21	1.59
86	Lower Wairau 1 Above	< 20	4910	6890	3540	
87	Lower Wairau 1 Below	< 20	2810	4760	1580	
88	Lower Wairau 2 Above	< 20	3730	5360	2530	
89	Lower Wairau 2 Below	< 20	2320	3250	1300	
90	Lower Wairau 3 Above	< 20	386	671	298	
91	Lower Wairau 3 Below	< 20	683	1230	339	
92	Rowley 1 A	< 20	27	37	51	0.35
93	Rowley 2 A	< 20	52	28	35	0.28
94	Rowley 3 A	< 20	68	39	45	0.29
95	Rowley 1 B	< 20	4	18	17	0.21
96	Rowley 2 B	< 20	4	17	12	0.22
97	Rowley 3 B	< 20	4	18	12	0.19
98	Rowley 1 C	< 20	5	22	14	0.27
99	Rowley 2 C	< 20	5	19	14	0.33

100	Rowley 3 C	< 20	20	35	22	0.35
101	Rowley 1 D	< 20	5	19	16	0.17
102	Rowley 2 D	< 20	5	20	16	0.16
103	Rowley 3 D	< 20	4	19	15	0.14
104	Rowley 1 E	< 20	4	17	16	0.85
105	Rowley 2 E	< 20	3	17	19	0.47
106	Rowley 3 E	< 20	4	17	15	1.05
107	Rowley 1 Above	< 20	3340	4970	2390	
108	Rowley 2 Above	< 20	2870	4220	1780	
109	Rowley 2 Below	< 20	2820	3900	1630	
110	Rowley 3 Above	< 20	4570	6210	3140	
111	Rowley 3 Below	< 20	2880	4010	1860	
112	Kaituna 1 A	< 20	141	90	193	1.50
113	Kaituna 2 A	< 20	174	117	224	1.04
114	Kaituna 3 A	< 20	131	99	253	0.96
115	Kaituna 1 B	< 20	21	31	28	1.48
116	Kaituna 2 B	< 20	8	26	17	0.40
117	Kaituna 3 B	< 20	15	25	18	0.47
118	Kaituna 1 C	< 20	194	125	255	1.69
119	Kaituna 2 C	< 20	132	87	86	1.44
120	Kaituna 3 C	< 20	180	142	470	1.86
121	Kaituna 1 D	< 20	174	118	234	1.53
122	Kaituna 2 D	< 20	138	98	139	0.98
123	Kaituna 3 D	< 20	167	121	312	1.25
124	Kaituna 1 E	< 20	5	17	16	2.93
125	Kaituna 2 E	< 20	4	16	15	3.02
126	Kaituna 3 E	< 20	4	18	17	4.24
127						
128	Kaituna 1 Below	< 20	2150	3560	1900	
129	Kaituna 2 Above	< 20	2200	3890	2030	
130	Kaituna 2 Below	< 20	3390	5260	2480	
131	Kaituna 3 Above	< 20	2050	3640	1710	
132	Kaituna 3 Below	< 20	2900	4720	2080	
133	Kaituna ¼ Round	< 20	3000	4610	2200	
134	Kaituna ¼ Round	< 20	2080	3250	1290	
135	Kaituna ¼ Round	< 20	3600	6510	2710	
136	Kaituna ¼ Round	< 20	3080	5350	2010	
137	Kaituna ¼ Round	< 20	3070	5270	2150	
138	Kaituna ¼ Round	< 20	3770	6410	3030	
139	Rarangi 03 A 1	< 20	27	47	80	1.19
140	Rarangi 03 A 2	< 20	22	41	45	4.74
141	Rarangi 03 A 3	< 20	15	27	27	3.61
142	Rarangi 03 B 1	< 20	14	20	10	0.50
143	Rarangi 03 B 2	< 20	7	20	7	3.41
144	Rarangi 03 B 3	< 20	9	19	19	2.67
145	Rarangi 03 C 1	< 20	26	35	40	0.44
146	Rarangi 03 C 2	< 20	32	38	53	0.82
147	Rarangi 03 C 3	< 20	14	25	41	3.09
148	Rarangi 03 D 1	< 20	22	30	34	0.48
149	Rarangi 03 D 2	< 20	29	36	52	0.90
150	Rarangi 03 D 3	< 20	9	22	25	3.72
151	Rarangi 03 E 1	< 20	8	18	5	1.75

152	Rarangi 03 E 2	< 20	5	16	4	1.21
153	Rarangi 03 E 3	< 20	2	14	6	5.52
154	Rarangi 1 A	< 20	83	103	150	0.24
155	Rarangi 2 A	< 20	48	62	217	0.43
156	Rarangi 3 A	< 20	57	49	97	1.59
157	2000 Rarangi 4 A	< 20	63	40	61	0.39
158	2000 Rarangi 5 A	< 20	59	28	48	0.30
159	2000 Rarangi 6 A	< 20	105	57	88	0.50
160	Rarangi 1 B	< 20	8	19	9	0.29
161	Rarangi 2 B	< 20	8	18	19	0.24
162	Rarangi 3 B	< 20	15	22	10	1.12
163	2000 Rarangi 4 B	< 20	12	17	6	0.09
164	2000 Rarangi 5 B	< 20	27	24	39	0.35
165	2000 Rarangi 6 B	< 20	29	22	18	0.07
166	Rarangi 1 C	< 20	97	81	170	0.18
167	Rarangi 2 C	< 20	72	89	339	0.28
168	Rarangi 3 C	< 20	58	72	215	0.69
169	2000 Rarangi 4 C	< 20	152	134	502	0.40
170	2000 Rarangi 5 C	< 20	237	104	265	0.52
171	2000 Rarangi 6 C	< 20	142	56	158	0.28
172	Rarangi 1 D	< 20	122	117	252	0.21
173	Rarangi 2 D	< 20	62	63	185	0.28
174	Rarangi 3 D	< 20	44	52	133	0.35
175	2000 Rarangi 4 D	< 20	104	61	210	0.30
176	2000 Rarangi 5 D	< 20	95	56	140	0.46
177	2000 Rarangi 6 D	< 20	79	52	147	0.27
178	Rarangi 1 E	< 20	2	16	5	1.24
179	Rarangi 2 E	< 20	3	15	5	4.35
180	Rarangi 3 E	< 20	3	18	4	3.02
181	2000 Rarangi 4 E	< 20	2	12	5	0.79
182	2000 Rarangi 5 E	< 20	3	14	5	0.94
183	2000 Rarangi 6 E	< 20	6	12	5	1.65
184	Rarangi 1 1.1	< 20	3	18	5	10.68
185	Rarangi 2 1.1	< 20	3	15	5	8.19
186	Rarangi 3 1.1	< 20	4	17	5	8.77
187	2000 Rarangi 4 1.1	< 20	2	12	5	1.29
188	2000 Rarangi 5 1.1	< 20	4	13	4	5.98
189	2000 Rarangi 6 1.1	< 20	5	12	6	7.91
190	Rarangi 03 1	< 20	2500	4360	2000	
191	Rarangi 03 1	< 20	2090	3700	1640	
192	Rarangi 03 2 Above	< 20	1690	2480	1230	
193	Rarangi 03 2 Below	< 20	1890	3010	1290	
194	Rarangi 03 3 Above	< 20	2380	3340	1540	
195	Rarangi 03 3 Below	< 20	2380	3390	1590	
196	Rarangi 4 Above	< 20	2650	3960	1700	
197	Rarangi 4 Below	< 20	1700	2410	910	
198	Rarangi 5 Above	< 20	3570	5650	2940	
199	Rarangi 5 Below	< 20	2170	3310	1120	
200	Rarangi 6 Above	< 20	3040	5050	2850	