The Effect of Chrome Copper Arsenic Treated Posts on Soil Chemistry and Biology in Kiwifruit Orchards

P Barlow [1] and C Prew [2]
[1] Barlow Soil & Crop 33 Levley Lane, Katikati, New Zealand. Barlowsc@xtra.co.nz
[2] Soil Foodweb Institute NZ Ltd 982 Kaipaki Road, RD 3, Cambridge, New Zealand. cherryle.melton@xtra.co.nz

Abstract.
We set out to investigate whether the use of CCA (Chrome copper arsenic) treated posts, used on kiwifruit orchards in the Bay of Plenty region of New Zealand had any negative effects on soil micro-organism or earthworm populations. Also measured was the rate of leaching of chrome, copper and arsenic from the posts, both laterally and temporally.

Four orchards aged 1,3,4,8 years respectivly were individually investigated. All had soils that were well drained, allophanic volcanic ash and with a sandy silt loam texture. For the soil chemistry and microbiology assessment, soil samples (top 150mm) were taken at three distances from the posts 10mm, 100mm & 1,000mm and earthworm counts were made at 100mm & 1,000mm distance from the posts.

The Microbes were assessed by direct counts using both brightfield (DIC) and epi-flourescence Microscopy. Earthworms were measured as direct counts per spade full of soil 100mm & 1,000mm distance from the posts. We found no difference in the size of the bacterial or fungal populations regardless of their proximity to the posts and in every case the Protozoa and earthworm counts were highest nearest to the posts. The biological counts varied greatly from one orchard to another due to differences in management practices and this meant that although the samples were replicated the results were not statistically significant.

Cr, Cu and As was extracted from the soil samples using total extraction and the content was assessed via graphite furnace spectrographic determination.
At 10 mm distance from the posts we found moderately high levels (µg g) of Cr III(73), Cr VI(10) , Cu (97) & As (114), but the level was lower at 100 mm distance from the posts at the acceptable levels of Cr III(8), Cr VI(2) , Cu (2) & As (12). We also found that the Cr (VI) to Cr (III) ratio decreased with distance at a greater rate than the general CCA leaching rate, indicating either lower Cr[VI] mobility or a change to the trivalent form of Cr.

Key words:
CCA, Chrome Copper Arsenic, Hexavalent Chrome, Tanalised posts, Kiwifruit, Earthworms, Protozoa.

Introduction
It is universal practice for horticultural fruit growers to use posts for structural support for their crops , especially with the varieties using dwarfing root stocks (e.g. apples & pears), cane fruits or vines e.g. grapes, raspberries & kiwifruit, which use 400 to 600 posts/Ha. These crops are all long duration perennials (kiwifruit >30 years) and they tend to be grown in high rainfall areas where untreated timber posts would decay very quickly. Therefore growers require that the posts must be rot resistant and that they should have good longevity.

Some researchers (Robertson B 2004) have recommended that concrete posts are a better environmentally safe choice because they are not troubled by rotting issues and that they do not contain any toxic preservatives. However concrete post use in kiwifruit orchards may have problems because the weight of the fruit loading may be up to 70t/ha plus the weight of the vine vegetation, and this heavy weight on the canopy wires exerts horizontal forces that could bend the posts to a degree that would fracture concrete posts. Therefore timber has the advantage of having strength for dealing with both compression weight and for horizontal strain, however as previously stated the timber post must be rot resistant. To achieve this it is common for the timber to be treated with preservatives such as:

a) Soaking in creosote
b) Pressure treated with either:
    a. Boron solution.
    b. Chrome, Copper Arsenic solution (CCA).

In New Zealand CCA treatment (Tanalising) is the most frequently used timber preservation method and this has been common practice for five or six decades. Cases of serious soil contamination from CCA appears to be limited to the sites where; timber was treated, bulk storage of new posts or where old treated posts were incinerated. In the orchard there does not appear to be any visible problems associated with the use of CCA treated posts, e.g. grass & other vegetation grow immediately adjacent to the posts and appears to be flourishing, earthworms are normally found in close proximity to the posts and after a few years in the orchard, posts become colonised with the growth of algae & lichen.

With the increasing demand for certified organic

crops to be grown in complete absence of chemical inputs questions of concern have been raised regarding CCA treated posts including;

1) **Is any Chrome Copper Arsenic Preservative Leaching from timber posts into the surrounding soil? If so at what rate?**

2) **Would using these posts cause any significant negative effects to soil organisms?**

3) **Are plants taking up any of the preservative and could this be harmful to human health?**

Britain's Department for Environment Food and Rural Affairs (defra) does not appear to have any Organic Standards regarding the use of timber preservatives in horticulture. However Britain's premier organic research institution The Henry Doubleday Research Association recommend that the CCA treated timber should be avoided (HRDA 2000)

In Marlborough NZ elevated arsenic levels were reported to have been found in a shallow aquifer and the finger of accusation was pointed at the abundant vineyard posts (NZ Grape Grower). This matter was investigated by Hort Research (Robinson et al 2004), where it was reported that CCA had leached from posts and that "25% of the samples exceeded the guideline levels in the soil for arsenic of 100 mg/kg and 10% exceeded levels for chromium of 100 mg/kg". However it should be clearly emphasised that the elevated levels they found were only in the samples taken from immediately against the posts or directly underneath the posts. And that in all cases where the samples taken at a distance of 50 mm or greater horizontally from the posts they found that the levels of chrome, copper and arsenic to be at acceptable levels.

In the United States concern about use of CCA treated timber in orchards has gone to the extent of generating of new official legislation by the National Organic Program (USNOP). This legislation requires that suppliers from foreign countries who wish to market produce in the USA, comply with the legislation and this includes New Zealand's certified organic Kiwifruit. New Zealand's leading organic certifying association "Biogro" has responded with the following ruling; (1st July 2002) "Timber treated with arsenate or other prohibited materials can not be used for new installations or for replacement purposes where it is contact with soil or livestock". Further clarification was given in the Technical Bulletin No.3 June 2003 (Biogro June 2003) " Examples of where treated timber can be used are -….. Timber structures used to support wires for crops, designed so that the crop is not in contact with the timber." In the same technical bulletin Biogro announced that they now classify CCA treated posts as a restricted input, where written consent is required before using any such posts on certified organic properties. The legislation appears to have been made with little or no scientific evidence, which had either demonstrated harm to the environment or to crops.

Whilst many organic growers will be breathing a sigh of relief at the reprieve of the Tanalised post there is still concern as to whether this issue could be raised again in the future and CCA treated timber posts could be prohibited without factual grounds for the decision. Therefore, the authors of this paper initiated a privately funded research project that sought to measure the rates of leaching of Chrome, Copper and Arsenic into the soil and to assess the impact of CCA treated posts on the populations of Earthworms and micro-organisms in the soil adjacent to posts in kiwifruit orchards.

Methods:

Study Orchards:

Four Kiwifruit orchards in the Katikati Bay of Plenty area were selected. In all cases the soil was well drained Yellow Brown Loam soil derived from Aeolian allophanic volcanic ash (sandy silt loam). Rainfall is high (normally in excess of 2m per year), therefore the soil naturally has a tendency to leach soluble elements

Sample gathering.

1) On all four orchards, separate soil samples (zero to 150mm depth) were taken from three separate distances from the posts;
   a. 10-35mm (replicated in each orchard)
   b. 100-125mm (replicated in each orchard)
   c. 1000-1025mm (replicated in each orchard)

   A total of twelve soil samples were taken and each sample was a composite of twenty cores taken from the respective distances from twenty different posts. After shaking each soil sample in a clean bucket they were divided into two, with half of each sample being sent fresh to SFI for microbiological assessment and the other half being air dried, passed through a 2mm sieve and sent to Brookside Laboratories Inc (BLI) for chemical analysis.

2) At the same time as soil sampling we also lifted twenty spade cubed sods of earth to make the earthworm counts which were taken from 100mm and 1000mm distance from the posts. Making 40 spade digs per orchard & 160 spade digs overall.
3) Soil sampling was in line with the post rows so that compaction from tractor wheelings was not an issue.
4) On each orchard 20 posts were drilled with a 10mm bit to a depth of 50mm and the shavings were collected and sent to BLI for chemical analysis. One sample per orchard.

5) Leaf sampling was carried out on 153 Orchards during November & December 2004 as per standard practice. (Hills Laboratories 2002)

Biology method: (SFI)
SFI assessed the fresh soil samples for microbiological populations using direct counts. The aerobic fungi and bacteria was assessed by:

a) Staining the fresh soil sample with Fluorescein Diacetate.
b) Mounting dilution of soil, buffer and agar on microscope slide.
c) Counting by eye & grid though microscope using both epi-fluorescence for active, aerobic fungi and bacteria, and brightfield light for total fungi. (Brock 2000)

Total bacteria counts (including anaerobes) were ascertained by direct counts with oil immersion, Fluorescien Isdothiocyanate stain and epi-fluorescence microscopy.
Protozoa counts were done by direct counts by microscopy on incubated plates using set dilutions of soil solution.
The samples were labelled in such a way so that the technician had no indication of either the proximity to the posts or the age of the orchard from where the samples were taken, this was to remove any subjectivity on the part of the technician.

Chemical analysis method (BLI)
The air-dried <2mm soil fraction samples were analysed using Graphite Furnace & Atomic Absorbsion technology. The parameters assessed included total Copper, total Arsenic , total Chrome and hexavalent chrome.

Statistical Analysis by SPSS Systat

Results (Chemistry).

We had expected to find a depletion of the levels of CCA in the timber posts with advancing age, but our results did not support this hypothesis (Table 1), conversely the oldest posts on orchard "D" had CCA levels above what would be expected in a new H4 treated post. The depletion effect may have been masked either by a variation in the quality of timber treatment or environmental issues.

With the lateral leaching we found a distinct gradient where Chrome (III & VI), Copper and Arsenic was found at decreasing levels with increasing distance from the posts (see Fig 1). This was in agreement with the findings of Robison B et al in the Hort Research Marlborough vineyards study.

Table 1 *CCA Content (mg/kg) Found in Posts*

Orchard	Age Years	Copper	Arsenic	Cr III	Cr VI	Cr III : VI Ratio
B	1	1270	1507	2404	99	24
A	3	1246	1724	2332	196	12
C	4	1461	1946	2645	241	11
D	8	2606	3862	3354	161	21

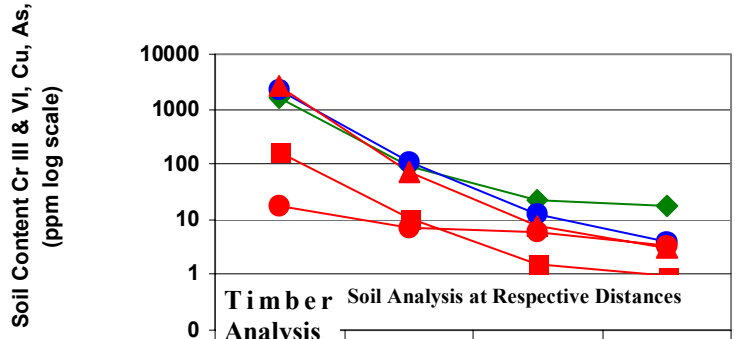
It is true that we found that the levels of arsenic at 10mm distance from the post exceeded the Australian National Environmental Protection Council's (NEPC) Guidelines for soil and groundwater, where chrome & arsenic is to be less than 100mg/kg and copper 1,000mg/kg. However at a distance greater than 100mm from the posts, the levels were well below the prescribed limits.

It is of note from our results that the ratio of the more harmful chrome [VI] hexavalent became progressively lower with increasing distance from the posts at a rate that was greater than the general diffusion rate. Therefore we can assume that either the Chrome [VI] was less mobile than Chrome [III] or it was being reduced to the trivalent form, probably it was a combination of both.

When considering the question of whether there is any accumulation of CCA in the soil over time; Our findings confirmed that to a minor degree copper appears to have been accumulating in the soil surrounding the posts (see Fig 2) but this was not at a level to be of any concern.

Fig 1

CCA Treated Timber & Soil Levels (Mean Average)



Timber Analysis	Soil Analysis at Respective Distances		
	10	100	1000
Copper	1646	97.33	22.22	17.55
Arsenic	2260	113.90	12.21	4.05
Chromium (III)	2683	72.65	7.67	2.96
Chromium (VI)	174	10.49	1.62	0.92
Chrome III : VI Ratio	17	7.05	5.78	3.26

We found no evidence of any accumulation of either chrome or arsenic over time. This is in agreement with the work of Canadian scientist Zagury G J (2003) researching leaching from CCA treated utility poles, he found that the soil's texture and organic matter content effected CCA diffusion to a far greater degree than the length of time that the posts had been in the ground.

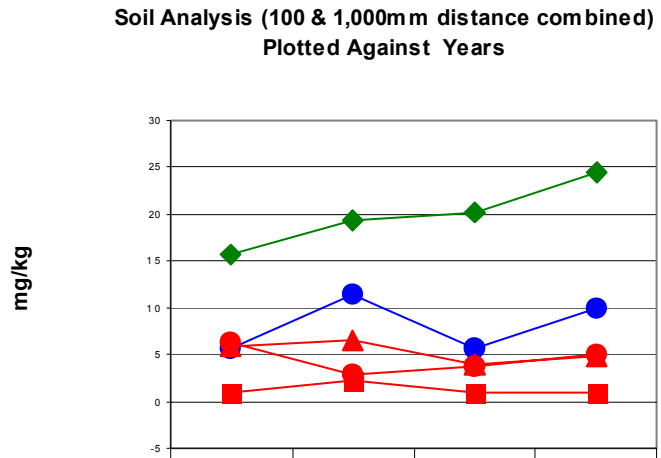
The interaction with iron & aluminium oxides is known to immobilise arsenic and this was demonstrated by Moore TJ et al (2000) who found that sites contaminated with arsenic could be ameliorated through the application of iron-sulphate. In our study all the orchards had a moderately low pH (see Table 2) which would tend to promote the diffusion of CCA, to counter this all of the study orchards had very well drained, oxygenated soils which would tend to oxidise the arsenic to the poorly soluble As[V] and the chromium to the poorly soluble Cr[III] form (Russell's p805).
If the high Loss-on-ignition (LOI) levels (Table 2) were taken as being mainly organic matter then we would expect very low copper mobility (Russell's p580), yet we found that copper was moderately mobile.
Much of the soil's high LOI result may be due to weight loss from the hydrated allophanic minerals loosing structural water. Allophanic minerals are composed of various forms of aluminium oxides which are known to reduce the mobility of arsenic, note the high Mehlich extractable aluminium levels on Table 2. Conversely iron levels are relatively low, for comparison a typical alluvial soil would have a Mehlich Extractable aluminium level of 500 to 800 ppm and iron from 100 to 180 ppm.

Table 2 **Backgound Soil Chemistry Properties**

		CEC	Loss-on	Mehlich Extractable ppm		
Orchard	pH	me/100g	Ignition %	P	Fe	Al
A	6.4	8.28	14.7	36	58	1191
B	5.7	11.29	14.2	62	52	1403
C	5.5	9.56	14.8	72	40	1429
D	5.7	10.23	15.1	61	40	1497

The orchards all had moderate Cation Exchange Capacity (CEC) (Table 2) therefore we would not expect copper to be greatly effected by leaching. The soil is known as having very high anionic retention qualities (about 90 to 95% phosphate retention), therefore we would not expect arsenic to be leaching at any appreciable rate. Our results confirm the expected low mobility of copper and arsenic, therefore on this soil type we can assume that the risk of CCA getting into ground water from orchard posts is minimal.

Fig 2



	1	3	4	8
Copper	16	19	20	24
Arsenic	6	11	6	10
Chromium (III)	6	6	4	5
Chromium (VI)	0.9	2.2	1.0	0.9
Chrome III : VI Ratio	6	3	4	5

Results (Biology).

Biological counts varied greatly from one orchard to another because of the respective orchard management practices e.g. fertiliser choice, herbicide usage and mowing regime etc. To illustrate this we have presented the earthworm counts separately for each of the orchards (see table 3). In all cases we found that the highest earthworm numbers were nearest to the posts. We can not be certain why this was so, but it may be because the worms were consuming protozoa (flagellates, amoebae & ciliates) and these were found to be more abundant near the posts (see table 4). Whatever the reason, the point is clear that the earthworms had no aversion to CCA treated posts.

Table 3 Earthworms (Mean average per spade)

Orchard	A		B		C		D	
Distance (mm)	100	1000	100	1000	100	1000	100	1000
Mean Ave	23.9	17.1	33.1	28.4	1.1	0.8	5.6	3.5
Std Dev	11.8	8.1	9.3	11.8	1.0	1.0	2.7	2.7

Similarly the Zagury (2003) study found no toxicity symptoms in Daphnia that were kept in water that had been leached from around CCA treated posts.

We found no obvious trends with bacteria or fungi

both as active and total counts, it is clear that in all cases the samples taken from nearest to the posts all had the highest microbial counts.

Table 4	Microbiological Populations Compared to Distance From Posts						
		10mm		100mm		1,000mm	
	Units	Mean	SDev	Mean	SDev	Mean	SDev
Active Bacteria	ug/g	7.3	0.9	6.5	1.2	6.7	2.0
Total Bacteria	ug/g	242.5	116.1	311.8	141.8	205.3	111.7
Active Fungi	ug/g	1.8	1.7	2.4	1.2	0.8	1.3
Total Fungi	ug/g	220	156	182	193	156	103
Flagellates	per g	14902	15714	8999	6332	9523	5388
Amoebae	per g	51119	22511	22056	24715	18076	1348
Ciliates	per g	904	695	180	274	532	841

Leaf Analysis Results:
Concerning uptake of CCA by plants we present general leaf analysis data for 153 kiwifruit orchards in the Bay of Plenty Region NZ 2004 (Table 5). All the orchards contributing to the leaf analysis were using CCA treated posts. We note that copper uptake was generally deficient, also there were no cases of excess copper. The desired range is as given by Hill Laboratories (2002) and are derived from work by Smith et al (1985). Chrome & arsenic were not included in the leaf results as the primary purpose of the analysis was for crop nutrition issues.
Marschner (2002) indicated that arsenic and phosphorus uptake in higher plants are using the same transport system and that arsenic uptake is normally the consequence of a phosphorus deficiency in a arsenic rich environment. Therefore if adequate phosphate fertilisers are used (as is common practice on orchards) then arsenic uptake by the plant is very unlikely, even if arsenic is at moderate levels in the soil. Our leaf analysis showed no cases of phosphorus deficiency (table 5).

Table 5	Kiwifruit Leaf Analysis Data 2004	
	Phosphorus (%)	Copper (ppm)
Orchards	153	153
Mean Ave	0.25	9.68
SDev	0.05	1.41
Min	0.16	6.00
Max	0.43	16.00
Desired Range	0.16 to 0.30	10 to 20

A small amount of chromium [III] in the human diet is now established to benefit glucose metabolism, however high levels of chrome especially the hexavalent form is known to be undesirable. Russell's (page 805) comments that "there is evidence that Cr [VI] is reduced (during transport) between the root surface and the stems, irrespective of the form that the Cr is supplied" and that "plant uptake is still very low (1 or 2 µg g) even when growth is reduced by Cr toxicity.
Chromium transport to the upper plant has been proven by study to be restricted with the roots, being three times higher in the roots than in the leaves of Creosote Bush grown hydroponically in a Chromium rich solution (Arteaga S. 2000). In most orchard situations it is the above ground part of the plant that is used for food purposes, therefore the likelihood of appreciable amounts of chromium from CCA treated posts getting into the human diet is very low.

Conclusions:

This kiwifruit orchard study and also the research made on both the Marlborough vineyards and the Canadian utility pole study, all agree that there is little or no evidence of leaching of CCA beyond 50mm to 100mm from the posts. Neither did we find anything, which would indicate that soil microbiology was being adversely effected. The consensus of agreement between the studies it that if there is any leaching risk, then it is the course textured gravely or sandy soils that would have the highest risk potential..

It is always prudent to keep all risks to an minimum even if they are thought to be low, and we should continue to explore alternatives through innovation, for example: In the Marlborough study Robinson (2004) sampled timber on CCA treated posts from both below ground and compared it with above ground samples and found that; chrome, copper and arsenic were all significantly higher in the above ground part of the post compared with timber from below ground. A plausible hypothesis was put forward that the post was acting as a wick drawing up water from the ground and it was evaporating from the post's above ground surface. Marlborough is a breezy low rainfall region, therefore this effect is most probable. In humid regions such as where this kiwifruit orchard study was made the annual rainfall is typically >2m, therefore we may wish to assist the wick effect by fixing waterproof plastic caps with an overhang on to the top of the posts to prevent rainwater from entering the top end-grain, which is the most absorbent part of the post. This should result is a net flow of water into the post from the soil, therefore leaching would not be an issue, this matter may be investigated through further research.

Acknowledgements:

For the use of their orchards: Allan Dawson, Scott Diggelmann, Roy Diggelmann, Merv Stockley.
For subsidising the Laboratory Fees Brookside Laboratories INC New Knoxville Ohio USA.
For assisting with sampling & Earthworm counts Toby Lancaster MSc. & Amelia Barlow BSc.

References.

Arteaga s. et al 2000, Spectroscopic confirmation of Chromium Uptake by Creosote Bush Using Hydroponics, Proceedings of the 2000 conference on Hazardous Waste Research.

Biogro 1st July 2002, Supplementary requirements to the BIO-GRO New Zealand Organic Standards for exports to USA.

Brock Biology of Microorganisms 9th edition Madigan M, Martinko J, Parker J (2000) pp 50-53

Hill Laboratories, 2002, Field Consultants Guide to Soil & Plant Analysis, Hamilton New Zealand

HRDA Fact sheet GG33, 2000, Wood Preservatives in the Organic Garden

Marschner Horst, 2002, Mineral Nutrition of Higher Plants 2nd edition, Academic Press p 40.

Moore, T.J et al, 2000, Ferrous iron treatment of soils contaminated with arsenic containing wood-preserving solution. Soil Sediment Contam.9:375-405

NZ Grape Grower Winter 2004 p8.

Robinson B, et al (2004) Hort Research Report to Marlborough District Council 18746, Results of an initial survey of the leaching from treated posts in vineyards in the Marlborough region ..

Russel's Soil Conditions & Plant Growth 11th edition, ed Alan Wild,

Smith et al 1985 Kiwifruit Nutrition. Diagnosis of nutritional disorders. AgPress Communications Ltd Wellington.

Zagury et al, (2003) Occurrence of Metals in Soil and Ground Water Near Chromated Copper Arsenate—Treated Utility poles, Journal of Environmental Quality 32:507-514