Current Practice and Future Land-use: The Sustainability of Productive Sector Environments

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Abstract

There are many cumulative contaminants used in primary productive sectors. Metals such as zinc (Zn) and copper (Cu) are present in pesticides applied to horticultural crops. Cadmium (Cd) may be applied as a co-contaminant in phosphate fertilisers. Arsenic (As), present in treated timber posts and historically used as a sheep and orchard biocide represents both a legacy contaminant and a current risk. Many of these metal pesticides are still in use and therefore continue to accumulate. Both Zn and Cd pose the most threat to pastoral farming systems with estimated years to reach maximum soil guideline levels of 75 and 27 years respectively for dairy production systems. Under horticultural production systems, Cu poses immediate threat. We estimate 7.7 years before soil guideline levels are exceeded under current management practices for avocado. Persistent organic pollutants (POPs) including dieldrin are no longer used in production systems within New Zealand but their persistence in soil means they still pose limitations to land-use. These organic pollutants may, in theory, degrade with time. However, our research indicates complex interactions with the soil matrix that limits their in situ degradation.

INTRODUCTION

New Zealand relies heavily on the condition of its productive sector environments. There is increasing concern that some current practices involving addition of cumulative contaminants are unsustainable, and likely to limit the future land-use options for some of our most productive soils. Overseas research indicates many areas of the world are currently facing limited land-use options following past or current practice (Kabata-Pendias and Pendias, 1992; McLaughlin et al., 1996).

A range of substances used in horticulture and pastoral farming contain appreciable quantities of certain metals. Metals can be present as impurities (McLaughlin et al., 1996), or as active ingredients (www.NZFSA.govt.nz). Sources to horticultural soils include fertilisers, manures, soil conditioners, and specific pesticides. Metal accumulation in pastoral soils also has direct relevance to the sustainability of horticulture in New Zealand, because most new horticultural developments involve conversions from pastoral land. Additional sources of metals to pastoral soils include veterinary medicines and animal remedies (Mills et al., 2004).

There is precedent for limitation of land use through the aggregate effect of cumulative contamination. Some persistent organic compounds such as dieldrin and DDT, formerly used in agriculture, were subsequently recognised as posing a threat to the environment, human and animal health. The presence of dieldrin and DDT either in localised 'hot spots' such as now disused sheep dipping areas, or as widespread contamination, as is the case with farms historically top dressed with superphosphate/DDT mixes to control grass grub, still limit land-use and farm management. Although both compounds have not been used for decades in New Zealand, their persistent nature has meant that past contamination still limits current and future land-use in many areas. However, some microbial populations are able to breakdown these contaminants. Therefore, it may be possible to remediate sites contaminated with organic compounds through the stimulation and enhancement of selected native soil microbial populations. This is not the case with metals.

Here we discuss the long-term impacts of current practice on the potential metal loading in New Zealand's productive soils. We use information of typical management practices in horticultural and arable systems to predict time to reach maximum contaminant guideline levels in soil. We also briefly discuss the management of sites, historically contaminated with recalcitrant organic compounds, for the production of high value primary produce.

MATERIALS AND METHODS

Metal accumulation from the application of pesticides in horticulture was assessed using the GROWSAFE calculator developed by HortResearch (www.growsafe.co.nz/projects/calculator.html). The model contains spray diary information for many horticultural and arable crops grown in a variety of regions throughout New Zealand. Given spray application rates, the level (kg/ha) of metal that is applied as the active ingredient, or forms an integral part of the active molecule can be calculated.

Cadmium values added to horticultural and pastoral soils are estimated given application rates of P required under different crop production systems (Clark et al., 1986). Although not all P applied to New Zealand soils is through application of super phosphate or phosphate rock we have assumed this for the calculations. Crops with high P requirements such as potato are routinely fertilised using superphosphate. Most P applied to pasture is as superphosphate. Cadmium levels in New Zealand superphosphate may be up to 280 mg Cd/kg P under current regulations (Cadmium, n.d.).

Livestock, including dairy cows, beef cattle and sheep are frequently dosed with Zn to counteract liver damage that may result from facial eczema infection. Given typical application rates of Zn for individual animals, stocking rates and Zn metabolism by the animals, estimates of Zn application to soil are assessed. Eventually all Zn administered to animals is passed to the soil in animal excrement. Generally all animals within a herd are treated with Zn if facial eczema infection is likely.

These data in conjunction with soil background levels of metal present and the estimated volume of topsoil allows calculation of years until guideline values are exceeded. Soil assumptions include a bulk density of 1.0, that metal accumulation occurs within the top 75mm and soil background metal concentrations of 50 mg/kg Zn (Bañuelos and Ajwa, 1991), 25 mg/kg Cu (Bañuelos and Ajwa, 1991) and 0.07-0.91 (0.5) mg/kg Cd (Zanders, 1998).

Maximum guideline soil values for Zn content are 600-800 mg/kg (Ontario Ministry of Environment and Energy, (1997)). No NZ guidelines for soil Zn levels are currently available. Maximum guideline values for Cu vary with soil type with 130 mg/kg for sand and up to 500-1000 mg/kg in clay (Ministry for the Environment (NZ), 1997a). Here a value of 200 mg/kg Cu is assumed for the calculations. Maximum guideline levels for Cd in soil are taken at either 3 mg/kg (Ontario Ministry of Environment and Energy, 1997) or 1mg/kg (NZWWA, 2003).

Arsenic contamination of soil has been assessed following a survey of the leaching of timber treatment chemicals, including arsenic, from posts in New Zealand vineyards. Arsenic concentration was measured in posts (both above and below ground portions) and in soil directly beneath the posts on six vineyards within the Marlborough region (Robinson et al., 2004). Samples (wood and soil) were analysed for As by a commercial laboratory (Hills laboratory, Hamilton, N.Z).

Dieldrin contaminated soil was collected from a former sheep dipping site. Dieldrin levels were measured at approximately 70 mg/kg initially. The dieldrin-contaminated soil was then placed in 15L pots and planted with willow (*Salix* sp.) or left bare. Dieldrin levels were measured by a commercial laboratory (Hills laboratory, Hamilton, NZ). Soil microbial activity was recorded throughout the experimental period using methods outlined by Chandler and Brooks (1991).

RESULTS AND DISCUSSION

Current Practice

Fertiliser and pesticide application in horticultural production systems do indeed pose a threat. Table 1 outlines the number of years before soil reaches guideline value for Zn, Cu and Cd under current management practices. Of most concern is the accumulation of Cu under apple, avocado, onion and grape production units. The accumulation of both Zn and Cd may pose a threat to land used for potato production. Although apple, kiwifruit and onion also require high levels of P fertiliser these crops are not routinely fertilised using superphosphate. Other forms of P including monoammonium phosphate contain less Cd (0.4 mg/kg) despite higher P content (specification sheet, Redox Chemicals New Zealand). Agricultural limes also contain Cd at levels between 1-2 mg/kg (McLaughlin et al., 1996).

Pastoral production systems also apply metals as dietary supplements and animal remedies. Generally application rates per ha are lower than horticultural systems however Zn still poses a threat under dairying (Table 1). Cadmium also poses a long-term threat even given a conservative soil guideline values used of 3 mg/kg (ANZECC/NHMRC, 1992). However, recent review of the NZ guideline Cd levels for soil has lowered soil Cd values to 1mg/kg. This has a significant influence on the time to exceed Cd concentration in soil given current practice (Table 1).

Arsenic leaching from treated timber posts has been previously reported (Zagury et al., 2003). Our results show elevated levels of As and Cu directly below treated posts and may account for soil contamination levels exceeding guideline values in these pockets of soil (Fig. 1, I). Where posts are intermittently dipped into fluctuating groundwater during the year, there may be a risk of As entering groundwater directly. The below ground portion of the posts shows reduced Cu and As levels when compared to above ground portions (Fig. 1, II)

Legacy Contaminants

Dieldrin levels do not show any decline over the course of our experiment (Fig. 2). However, stimulated microbial activity does occur in the planted pots when compared to the unplanted controls (Fig. 3). Published half-life values for dieldrin in soil vary from 2.5 years (Brown, 1978) up to 11 years (Ministry for the Environment (N.Z), pg 8.67, 1997b). This variation in half-life values, and our data, illustrate the complex interaction between dieldrin and soil biotic and abiotic factors. This indicates that in some soils dieldrin may degrade relatively quickly however other soil types, such as our experimental soil, can cause dieldrin to be more recalcitrant and therefore limit future land-use for longer. Further sequential extraction of dieldrin from soil needs to be carried out before accurate assessment of total soil dieldrin concentration can be done and management of these soils recommended.

CONCLUSIONS

The accumulation of heavy metals in productive sector soils due, to the application of fertilisers and pesticides, is of special concern because it is largely irreversible. Unlike organic compounds, metals cannot degrade over time. Key metals of concern in New Zealand include Cd, Cu and Zn.

Many organic compounds degrade naturally over time however some POPs such as dieldrin may be extremely recalcitrant. Dieldrin is listed in the 'dirty dozen' (UNEP, 2002).

This paper highlights the need to proceed with caution and with regard for current practice on productive soils. Legacy contamination limits current land-use and current management practices may limit future land-use prospects.

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Tables

Table 1. Years to reach guideline soil values given current application rates in selected horticultural, arable and pastoral production systems.

Crop	Application rate			Years to guideline value (top 7.5cm)			
	Zn (kg/ha/yr)	Cu (kg/ha/yr)	Cd * (g/ha/yr)	Zn	Cu	Cd* (3mg/ kg)	Cd* (1 mg/kg)
Potatoes	7.5	0.6	22.4	65	218	83	16.74
Grapes	4.5	4.4	2.5	108	30	748	150
Onions	2.4	6	18.2	203	22	102	20.6
Asparagus	0	1.3	8.4		100	222	44.6
Maize	0	0	11.2			166	33.4
Kiwifruit	0	2.2	16.8		60	111	22.32
Apples	1.4	4.48	21	348	29	89	17.85
Avocados	1.4	16.93	10.5	348	7.7	178	35.71
Peas	0	0	11.2			167	33.38
Broccoli	0	0.13	14			133	26.78
Dairy	6.72	86	14	75	1523	133	27
Sheep	5.77	16	7.76	84	8187	240	48
Beef	5.04	65	7.76	96	2015	240	48

*Assumes all P added to system is in the form of superphosphate which has 280 mg Cd/kg P.
Blank cells within the table indicate that the metal is not routinely used in this crop.

Figures

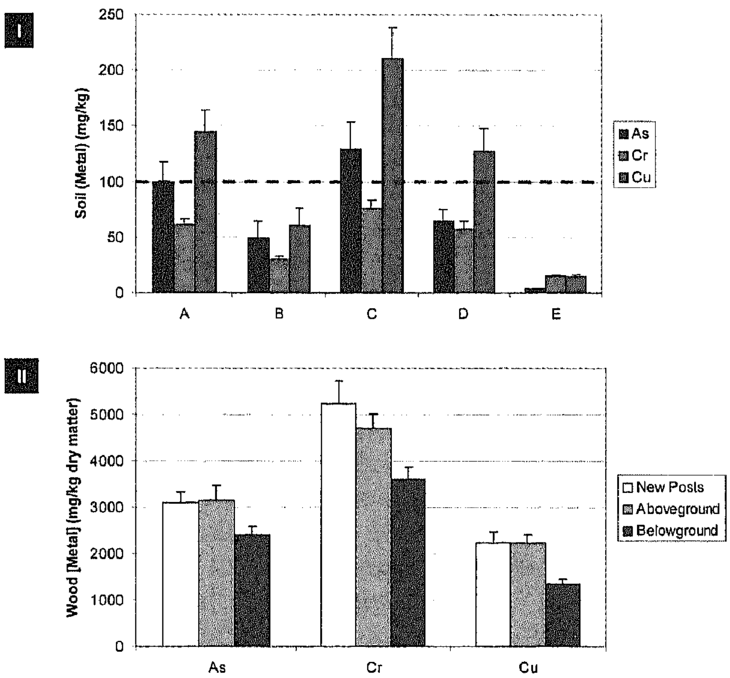

Fig. 1. Average soil (I) and wood (II) CCA concentrations across all sites sampled. "Aboveground" and "Belowground" refer to post wood sampled aboveground and belowground respectively. The locations of samples A (adjacent to post), B (50mm from post), C (directly under post), D (100mm below post) and E (control). Bars represent the standard error of the mean (n=27 for all means except 'New Posts' where n=6). The dashed line is the NEPC (Australian National Environmental Protection Council) guideline for arsenic in soil.