The Accumulation of Copper, Lead and Arsenic in Orchard Soils and its Effects on Plants

A thesis submitted by

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SUMMARY

The objectives of this work were to assess the extent and consequences of the accumulation of copper, lead and arsenic from sprays in the soils of apple and pear orchards in Australia. In field investigations, the concentrations of copper, lead and arsenic in surface soils and their re-distribution throughout the soil profile were studied, as well as the seasonal variation in their uptake by pasture plants. Glasshouse pot experiments were used to assess the effects of soil temperature, pH, waterlogging and fertilizers on the growth and content of vegetables.

The area of Australia on which apple and pear trees are grown has declined rapidly since 1970 and is now estimated to be less than half of the post-war peak of approximately 50000 ha. This decline in area was caused by declining profitability and losses of traditional markets in Europe and was accelerated by the Fruitgrowing Reconstruction Scheme (1972-6) which encouraged growers to clear or partial fell unprofitable orchards. Orchard soils have accumulated residues from copper-containing and lead arsenate sprays over many decades. The extent of accumulation of copper, lead and arsenic in soils, and their possible effects on agricultural activities following tree removal have not been investigated in Australia.

A number (98) of surface soils were sampled from orchards or former orchard areas in South Australia and Tasmania. The copper, lead and arsenic concentrations exceeded 300, 550 and 100 $\mu g\ g^{-1}$, respectively, which are 20 to 30 times the concentrations usually found in uncontaminated soils. Copper and lead extracted by DTPA and EDTA were linearly correlated with total concentrations. The ratios of lead to arsenic in the surface soils, when compared to the ratio in lead arsenate spray, suggested that losses of arsenic had occurred, especially in the Tasmanian soils. Examination of a series of soil

profiles from the Huonville area confirmed that substantial leaching of arsenic occurs in coarse textured soils relative to lead and copper which were both retained in the top 25 cm of the orchard soils. Data are also presented for a representative soil profile from the Mt. Lofty Ranges near Adelaide which suggested that an additional mechanism for loss - as volatile organic arsenic compounds - may occur in these soils.

Pasture plants growing on former orchard soils were sampled from near Adelaide and Huonville and were found to have higher than normal concentrations of copper, lead and arsenic. The copper concentrations of the plants sampled near Adelaide varied with species and occasion of sampling, many being in excess of 30-40 $\mu g\ g^{-1}$. The lead concentrations of the plants were usually less than 5 $\mu g\ g^{-1}$ despite high concentrations in the soil, although *Actotheca calendula*, which grew on a soil with a lead mineralization, contained up to 75 $\mu g\ g^{-1}$. The arsenic concentrations of the plants were low (usually about 0.5 $\mu g\ g^{-1}$), but marked increases in concentration to about 2 $\mu g\ g^{-1}$ occurred in all species at the end of the growing season. The copper, lead and arsenic concentration of the tops of *Trifolium repens* and *Lolium perenne* sampled in the Huonville area differed little from what might be expected from plants grown on uncontaminated soils and showed no relationship with the total concentration of the elements in the soils.

In a pot experiment, it was shown that increasing the soil temperature of an orchard soil and a mineralized soil from 12°C to 22°C resulted in increases in yield and in the concentration of copper, lead and arsenic in the tops of subterranean clover, silver beet and radish. Small but significant increases were also observed in copper and lead concentration of radish roots grown in the orchard soil.

The pH of eight soils (four orchard soils, two dosed with lead, arsenic and copper, and two affected by mining or mineralization) was modified by treatment with sulphur, gypsum or calcium carbonate. Silver beet and radish were grown. The effects of the treatments on the copper and lead contents of the plants were largely attributable to pH and it was found that the concentrations in the plants decreased with increasing pH whereas the concentration of arsenic in the plants was usually much less sensitive to soil pH. Visual symptoms of toxic effects usually occurred only on the most acidified treatments and were more likely to be attributable to other elements such as manganese or aluminium than to the elements being studied. The results suggested that DTPA extracts for copper and lead are not suitable for use on contaminated soils in situations where pH changes occur. An additional "prior-waterlogging" treatment resulted in no consistent effects on plant growth or composition.

The response of silver beet grown on two orchard soils to fertilizer phosphorus, sulphur or nitrogen was investigated in pot experiments. The effects observed were usually small, but beneficial in decreasing the concentrations of copper, lead and arsenic in the plants. Nitrogen applications may have a more marked effect in decreasing the arsenic concentration of silver beet.

The most serious consequence of the accumulation of copper, lead and arsenic appears to be the possibility of chronic copper toxicity to sheep grazing pastures established on orchard soils. Some risk may also be presented to horses if sufficient lead is ingested as soil contamination of fodder. The arsenic concentration of silver beet and radish grown on soils containing 95-120 $\mu g\ g^{-1}$ of total arsenic may approach the current health limit for humans and it is this element which has the least margin for safety. The copper, and possibly the lead concentrations of vegetables grown on orchard soils are unlikely to exceed the established health limits.

Statement

This thesis contains no material that has been accepted for the award of any other degree or diploma in any university, and, to the best of my knowledge and belief, it contains no material previously published or written by another person, except when due reference is made in the text.

Richard Hugh Merry.

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