Vegetables growing in an old orchard.

The soil layers of a Tasmanian study site at Grove Sand. The top darker grey layer contains large amounts of copper and lead; the deeper thin brown layer (50–60 cm depth) contains most of the arsenic. Each segment in the tape represents 10 cm.

The legacy of orchards

Through a popular fairytale, fear of poisoned apples is instilled in most of us at an early age. In later life, many people conscientiously scrub or rinse fruit before taking a bite, to remove any chemical spray left on the surface. But, apart from its produce, can the orchard environment itself be contaminated by the pesticides used on fruit trees?

Mr Richard Merry of the CSIRO Division of Soils in Adelaide has been studying the question in the orchard regions of South Australia and Tasmania. His work is the first to document the extent to which the copper, lead, and arsenic in some orchard sprays has accumulated in Australian soils, and the effects this accumulation may have on later land use.

Dwindling hectares

For nearly a century, fungicidal sprays such as the copper-containing Bordeaux mixture and copper oxychloride have been used in apple, pear, and stone fruit orchards, and on vineyard and vegetable crops. Lead arsenate has also been used during this period to control a range of chewing insects, especially codling moth.

When the United Kingdom joined the European Economic Community in the late 1960s Australia's main market for apples and pears was lost, and since that time the area of country taken up by orchards has decreased. Many of these former orchards are close to the cities of Adelaide, Hobart, and Melbourne. Over the last 40 years, at least 30 000 ha of land originally producing pome fruits has become available for other uses — grazing, urban development, and vegetable-growing.

To determine the extent and rates of accumulation of copper, lead, and arsenic in surface and subsurface soils, Mr Merry, Dr Kevin Tiller, also of the Division, and Dr Angus Alston of the University of Adelaide sampled the top 10 cm of soil from orchards and former orchards in South Australia and Tasmania. Their results showed that copper, lead, and arsenic were present in amounts up to 25–35 times the concentrations they measured in 'uncontaminated' agricultural soils.

Although surface soil concentrations of copper and lead appeared to parallel each other, many Tasmanian soils appeared to have arsenic concentrations well below those calculated from the mass ratios of the elements in the lead arsenate spray used on the orchards. In other words, arsenic was disappearing from surface soils at a higher rate than either lead or copper.

In search of an explanation, the researchers examined many representative soil profiles for features that could influence the mobility of arsenic, copper, and lead. Near the surface, most soils contained enough clay and oxide minerals and sufficient organic matter to enable them to strongly adsorb copper, lead, and arsenic, making leaching of these elements unlikely. The profiles showed no evidence of their accumulation below 25–30 cm.

However, in some Tasmanian soil profiles, arsenic accumulated deeper, and in some cases disappeared completely. Mr Merry proposed two mechanisms to explain this loss of arsenic from the surface soil. Leaching of arsenic in the acid sandy soils may have been assisted by phosphate (PO_4) from fertilizers, which is adsorbed in preference to arsenate (AsO_4) and has a similar molecular structure. This would displace arsenic to deeper adsorption sites. Alternatively, arsenic may be lost from the soil to the atmosphere following microbial transformation to the volatile alkyl arsine.

The disappearance of arsenic from the surface of old orchard soils doesn't mean that it no longer presents an environmental hazard — leached toxic elements may find their way into groundwater and contaminate plants or animals in streams and related parts of the environment.

Mr Merry tested sediments from drainage channels for copper, lead, and arsenic and found traces of arsenic in some of them. He believes that arsenic is largely dispersed, but does not rule out the possibility that some accumulation may have occurred.

The pasture plants — ryegrass and white clover — growing on some of the former orchard soils in Tasmania were also analysed for copper, lead, and arsenic concentrations. The concentrations in the plants generally were unrelated to total soil concentrations of the elements.

Although copper levels in these plants from Tasmania were low, other pasture plants sampled in South Australia had concentrations much higher than the recommended safe level for sheep of 20 parts per million (p.p.m.). Soil temperature differences between Tasmania and South Australia offer a partial explanation. Increases in temperature can cause plants to accumulate more copper than those grown at lower temperatures, as Mr Merry's glasshouse experiments had shown. In his work on South Australian sites, Mr Merry found copper levels of up to 50 p.p.m. in pasture plants, even though lead and arsenic levels were below safe standards.

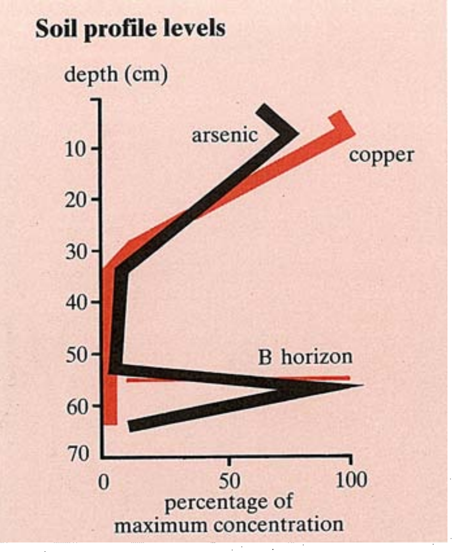
The pasture plants in both studies looked normal, displaying no obvious toxicity symptoms — a significant observation given that many of Australia's former orchards now support pastures, and many existing orchards with high concentrations of copper, lead, and arsenic in the soil support good stands of grasses (usually with legumes) as ground cover. Accumulations of toxic elements, especially arsenic and copper, could nevertheless cause decreased yields, a possibility needing further study.

Despite the results on uptake by Tasmanian pasture plants, Mr Merry's earlier work and studies by other scientists have shown evidence of a relation between concentrations of lead, copper, and other elements in the soil and those in pasture, crop, and vegetable plants grown in contaminated soils in field and glasshouse experimental plots.

The lack of a simple correlation between plant and soil levels of toxic elements may be due to the effects of other toxic elements, fertilizers, and different acidities found in contaminated soils.

Danger to stock

As far back as 1951, a CSIRO researcher, Dr L.B. Bull of the then Division of Animal Nutrition, found that toxaemic jaundice and haemoglobinuria among sheep grazing in the Adelaide Hills were caused by excess copper in pastures. Concentrations there of 30–40 p.p.m. led to chronic copper poisoning in sheep. Later studies showed that poisoning also occurs on pastures dominated by subterranean clover with 'normal' concentrations of copper but with low molybdenum. In both cases, the problem results from the animal's high intake of copper relative to molybdenum and sulfur.



At the Grove Sand site, most of the copper and lead present remains within the top 10–20 cm of soil, while most of the arsenic sits on, or just below, the B horizon. In some soils, arsenic is virtually absent from the upper layers.

Cattle are less sensitive to copper toxicity, and horses, pigs, and humans can tolerate relatively high concentrations in the diet. Grazing animals consume soil adhering to plant material, so copper, lead, and arsenic additional to that in the pasture plants would contribute to the total amounts consumed.

Mr Merry has attempted to establish the effect of former orchard soils on vegetables grown for human consumption. By means of glasshouse experiments, he examined the effects of soil temperature, acidity, and fertilizers on the copper, lead, and arsenic contents and growth of both silverbeet and radishes.

In the temperature experiment, silverbeet grown at 22°C had almost twice the content of copper as the same species grown at 12°C, although the pasture plant sub clover showed a less dramatic response than the vegetable.

Plant uptake of copper and lead appeared to increase with increasing acidity. Liming of soil (which decreases acidity) decreased plant concentrations of toxic elements; arsenic uptake, however, was unaffected by acidity changes.

In many orchard areas, large amounts of fertilizers are used every year. Mr Merry applied equivalent amounts of fertilizers to the orchard soils in glasshouse pots and found that, with the exception of nitrogen, they had little immediate effect on copper, lead, and arsenic concentrations. But they are likely to reduce plant uptake in the long run — the role of phosphates in reducing arsenic concentrations in topsoil has already been mentioned.

Addition of nitrogen to vegetables produced a dramatic result: as the dosage of nitrogen increased, arsenic concentrations in silverbeet fell greatly, a result that requires further investigation.

The pot experiments indicated that the copper, lead, and arsenic contents of vegetables grown on former orchard soils would not exceed established standards for human consumption. Anyway, vegetables grown in contaminated areas are likely to be mixed with produce grown in normal soils.

But Mr Merry cited at least two potentially dangerous circumstances for humans: people growing, and largely consuming, their own vegetables on highly contaminated former orchard soils; and children in such areas eating dirt, a well-documented childhood practice.

In future, the risk of lead and arsenic toxicity will probably fall as their usage in pesticides ceases altogether. The commercial application of lead arsenate to crops in Australia has fallen rapidly since the introduction of organic chemicals, and it is no longer used on crops grown for export. But the use of copper-containing sprays will continue and some monitoring of copper concentrations seems necessary to avoid the development of chronic toxicity in stock.

How do our orchard and former orchard soils compare with those in other countries? Copper, lead, and arsenic from orchard sprays accumulated in the South Australian and Tasmanian soils to concentrations greater than 300, 550, and 100 p.p.m. respectively (compared with normal levels of 20, 10, and 5). Copper concentrations were as high as, or higher than, those reported from Florida and Canada, but much lower than those in some European vineyards. Lead and arsenic concentrations in Australia are closer to those reported from Canadian orchards, but the highest arsenic concentrations are much lower than those reported for some orchard soils in the United States.

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More about the topic

Accumulation of copper, lead and arsenic in some Australian orchard soils. R.H. Merry, K.G. Tiller, and A.M. Alston. *Australian Journal of Soil Research*, 1983, **21**, 549–61.

'The Accumulation of Copper, Lead and Arsenic in Orchard Soils and its Effects on Plants.' R.H. Merry. M.Ag.Sc. Thesis, University of Adelaide, 1980.