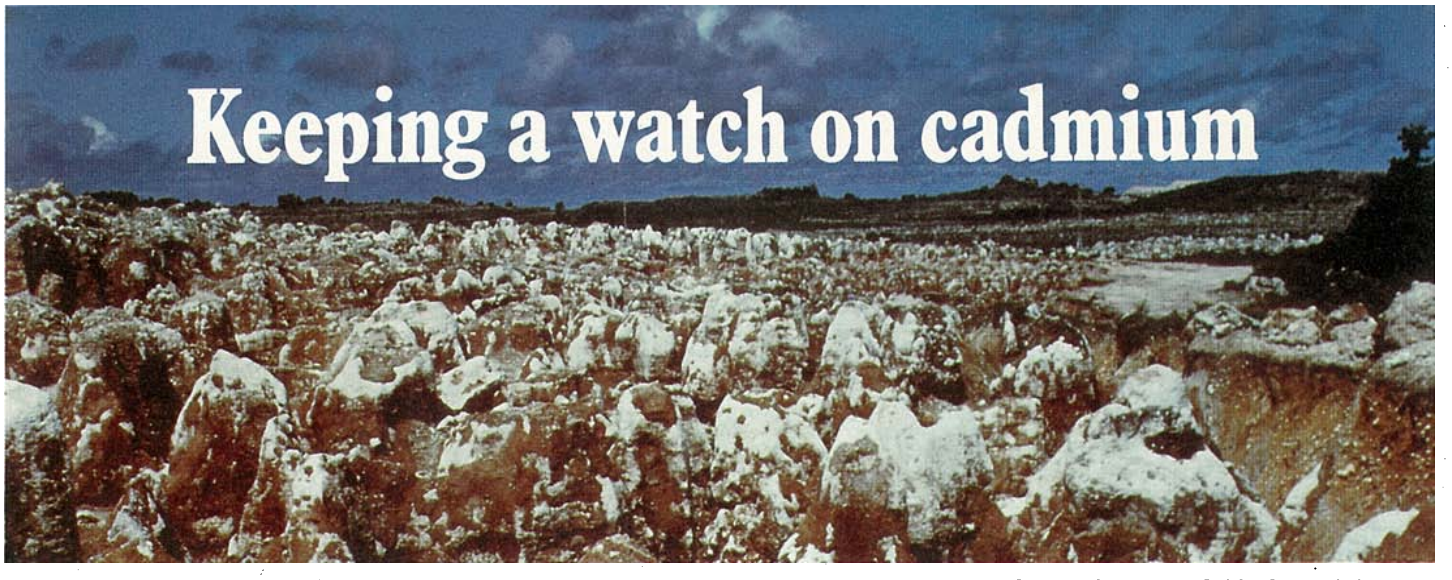
Keeping a watch on cadmium



A Nauru phosphate field after mining—pinnacles of coral are exposed.

After water, superphosphate is probably the substance added in greatest quantity to Australia's soil. Phosphorus deficiency is a fact of life in most of Australia's food-producing areas, and fertilizers that remedy it—mainly superphosphate—account for at least 85% of our fertilizer consumption. Unfortunately, when superphosphate is spread across the land, so are small amounts of the impurities it contains, one of which is the toxic metal cadmium.

Over the past few years Dr Colin Williams and Dr John David, of the CSIRO Division of Plant Industry in Canberra, have examined what happens to this cadmium. They have found that most is retained in the top portion of soil that crop and pasture plants take their nutrients from, and that the plants incorporate some of the metal in their tissue. However, the quantities appear to be too small to cause concern, except possibly in vegetable plots that have been fertilized very heavily for many years.

Research hasn't yet revealed any function for cadmium in the human body, although very small quantities can be taken in apparently without ill effect. The World Health Organization has provisionally recommended an intake limit of 400 to 500 micrograms (millionths of a gram) a week. A study in the United States in 1969 suggested that the average American was swallowing about half this amount with his food.

Dr Williams' and Dr David's analyses of vegetables grown in various parts of Australia revealed a large range of cadmium concentrations, but the averages for particular vegetables were very similar to those recorded in the American study. So Australians probably take in similar amounts with their food. Smaller amounts can also be absorbed from air pollution, cigarette smoke, and other sources.

The W.H.O. limit is well below levels at which toxic effects have been observed, but more information is needed before a definite safe limit can be set. The poisonous effects of big doses are immediately obvious. Smaller doses taken over a period can cause chronic poisoning, with symptoms including severe and painful kidney disease and bone disorders. In the only instance recorded so far, rice irrigated by water contaminated with cadmium from mining tips chronically poisoned more than 200 people in a Japanese farming community in the 1960s.

Source of the cadmium

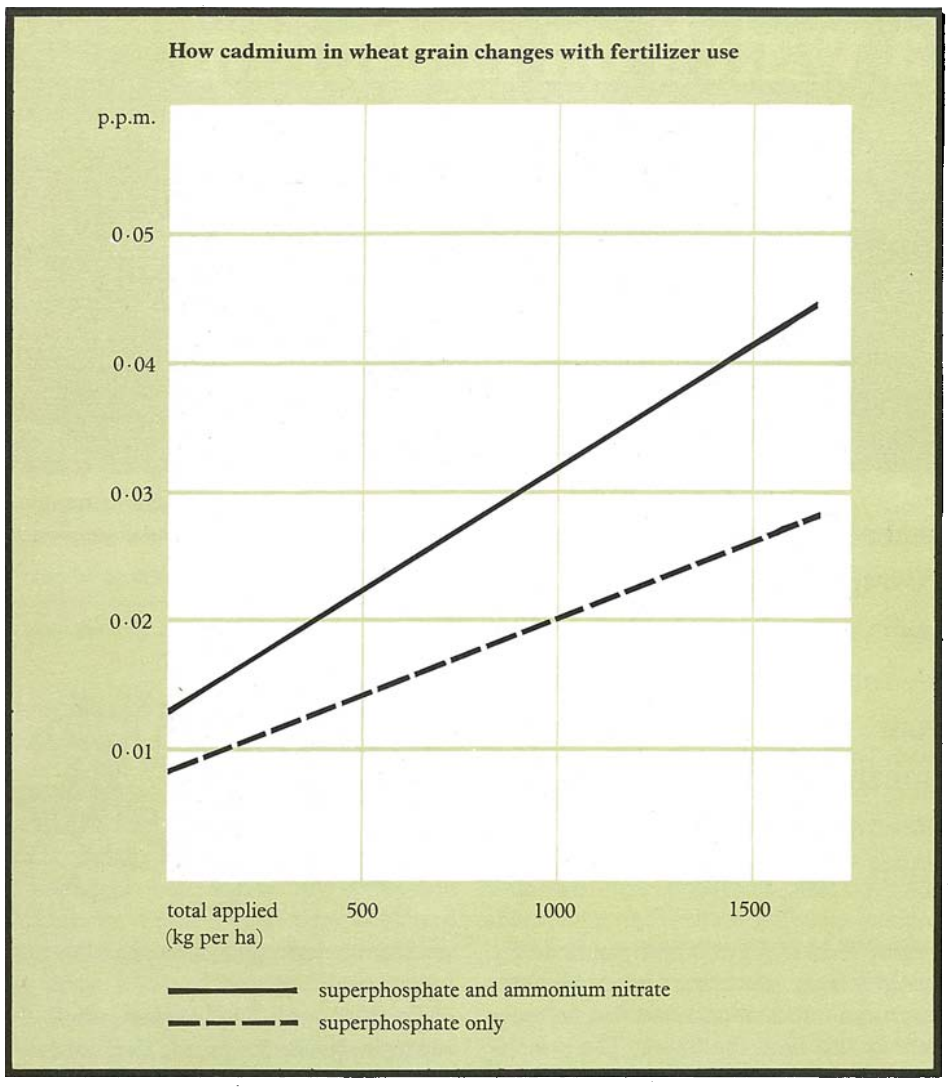
Australia's superphosphate is made from rock phosphate imported mainly from three islands—Nauru and Ocean Island, north-east of Australia, and Christmas Island south of Java. The phosphate had formed from guano, the accumulated droppings of seabirds. Most of the cadmium probably found its way there via the birds' food; some of the small marine organisms that the birds would have eaten accumulate quite high concentrations from their own food.

Dr Williams and Dr David measured cadmium in rock phosphates from the three islands and in superphosphate made in Australia, and found that most if not all of the cadmium originally present ends up in the fertilizer. The average concentration in superphosphate is about 40 parts per million.

To find out what happens when the superphosphate is spread, they analysed soil from fields with known histories of fertilizer application and from adjacent unfertilized areas. The fertilized fields had been used for growing pasture, wheat, potatoes, tobacco, celery, or other vegetables, and five different soil types were represented.

The scientists' readings indicated that at least 80% of the total amount of cadmium added since superphosphate was first used had been retained in the cultivated portion of four of the five soil types. The exception was a light sandy soil used for vegetable-growing. There, about half of the cadmium had gone from the cultivated layer; probably it was leached out by the rain.

To gain an idea of the impact of the heavy superphosphate use by commercial vegetable-growers—perhaps 2500 kg per ha, compared with about one-tenth of that amount on crops and pastures—the scientists analysed soil from seven market gardens. Its average cadmium content turned out to be about ten times greater than that of nearby uncultivated soils—0·452 p.p.m. compared with 0·048 p.p.m. Accurate records of the amounts of fertilizer used by the market gardeners were not available, so the scientists could



Cadmium uptake by wheat grain is very small, but increases with superphosphate application. Why ammonium nitrate boosts cadmium uptake has not been determined.

Plants differ greatly in the amounts of cadmium they absorb. The scientists suggest that levels in vegetables should be watched.

Some dry-weight cadmium levels measured by Dr Williams and Dr David

	p.p.m.
Australian superphosphate	20–52
unfertilized soil	0·013–0·13
soil fertilized with superphosphate	0·076–0·560
radish roots (no superphosphate)	0·10–0·28
radish roots (superphosphate)	0·14–0·73
wheat grain (no superphosphate)	0·008
wheat grain (5 years' superphosphate)	0·028
potatoes from shops	0·12–1·21
tomatoes from shops	0·10–0·13

not work out the proportions of added cadmium that had remained in the soil.

Measuring uptake

In another experiment, Dr Williams and Dr David took soil from adjacent fertilized and unfertilized areas, put it in pots, and planted radishes. When the plants were 5 weeks old, they measured the cadmium concentrations in the radish tops and roots.

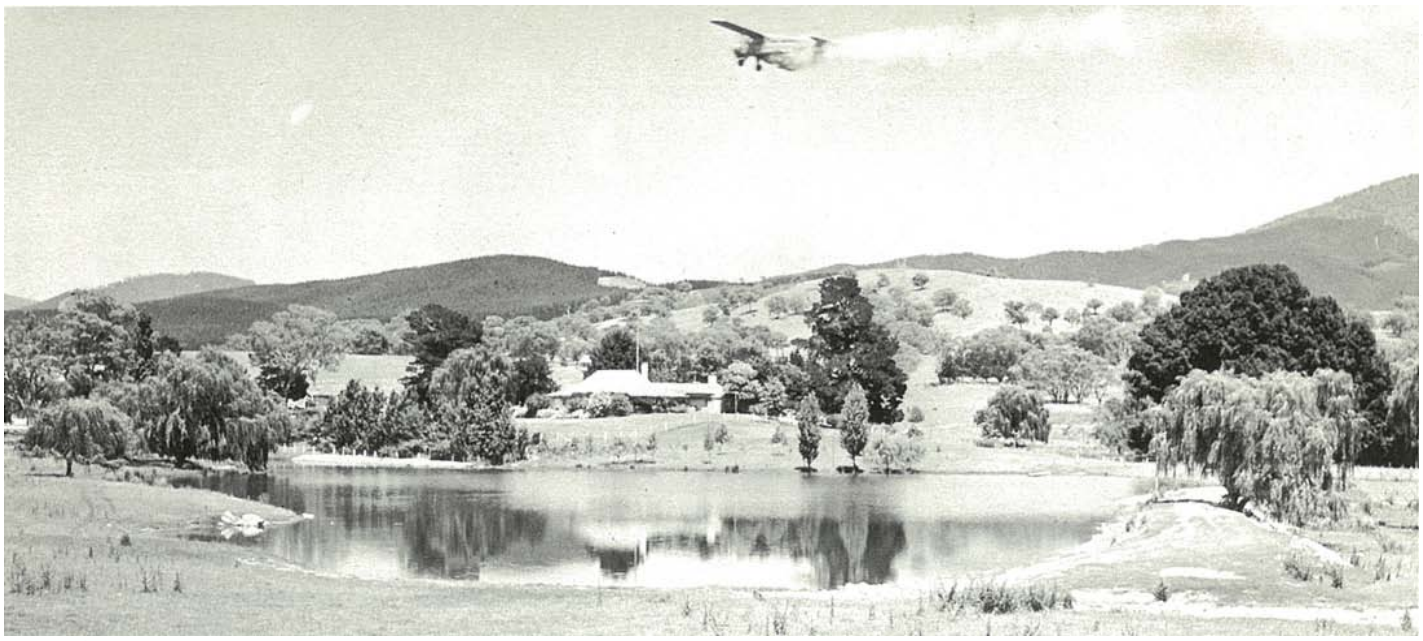
Two of the fertilized soil samples had also been limed, and the radishes grown in these had slightly lower cadmium contents than those grown in the soil from nearby unfertilized plots. This was despite a considerably higher cadmium level in the soil. It seems that cadmium becomes less available to plants as the alkalinity of soil increases.

However, when the alkalinity was about the same in fertilized and unfertilized soils, the amount of cadmium taken up by the radishes increased with the soil's cadmium content. The scientists used radishes in the experiment because these grow quickly and can get by in soil with low fertility.

In an experiment to look at the effects of superphosphate in wheat-farming, they took soil and grain samples from plots given various fertilizer treatments as part of another research project. Their soil analyses revealed cadmium concentrations rising proportionally with the total amount of superphosphate applied. When superphosphate was the only fertilizer used, the cadmium content of the wheat grain increased in the same manner; in 5 years it rose from 0·008 p.p.m. to a still very low 0·028 p.p.m. Unexpectedly, however, application of ammonium nitrate also led to an increased cadmium content in the grain. The scientists haven't yet found an explanation for this.

Turning to pastures, they found a similar direct relation between the amount of superphosphate added and the cadmium content of subterranean clover. The scientists calculate that, with normal commercial application of superphosphate to crops and pastures, cadmium levels in most farm soils would have increased by some 0·1–0·2 p.p.m. over the last 50–60 years.

A general conclusion from the experiments, only some of which have been described here, is that cadmium spread with superphosphate accumulates in the cultivated layer of soil, and as long as it continues to be spread concentrations can be expected to keep rising. Also, the amount of cadmium taken into plant



Spreading superphosphate.

tissues generally increases as the concentration in the soil grows. But other factors, particularly how acid or alkaline the soil is, can have big effects on uptake of the metal.

Plants differ greatly in the amounts of cadmium they absorb, and some portions of individual plants accumulate much more than others. Very little finds its way to cereal grains, so there seems to be no cause for concern there. Pasture plants take up more, but little of this finds its way into meat and other animal products.

The scientists suggest that cadmium levels in vegetables should be watched, although at present these seem, on the basis of the limited evidence available, to be generally well below harmful concentrations. The risk exists that heavy use of superphosphate may eventually build up the cadmium content of soil in some market gardens, and hence of the vegetables these produce, to unacceptable levels.

Fortunately some strong influences are working against this result. Important among them, the continual sprawl of our cities tends to keep market gardens moving outwards, off soil that has been fertilized for decades. Another is the fact that our phosphate sources with the highest cadmium concentrations are running out quite rapidly. One of them, Ocean Island, will probably be exhausted in about 5 years and the other, Nauru, has only enough to keep up supplies for perhaps another 25 years.

The third source being drawn on now, Christmas Island, produces phosphate with about half the cadmium concentration of the material from the other two islands, and it should be able to keep up supplies for a long time still. The source likely to be tapped next is deposits in northern Queensland, and their cadmium concentration is much lower—about one-tenth of the Nauru–Ocean Island level.

More about the topic

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The effect of superphosphate on the cadmium content of soils and the uptake of cadmium by plants. C. H. Williams and D. J. David. *Australian Journal of Soil Research*, 1973, **11**, 43–56.

Metals are spread widely

Cadmium reaches its highest concentrations in nature in compounds associated with zinc ores, and the pure metal is produced mainly as a by-product of zinc recovery. However, like many other metals, it is also scattered in very small quantities throughout the land and living things.

Trace quantities of some of these metals are needed by plants and animals for healthy growth. Much of Australia's agricultural soil is deficient in varying combinations of them, so small quantities are spread where they are needed, usually as additives in superphosphate. Metals now added to the soil in different parts of Australia include boron, cobalt, copper, manganese, molybdenum, and zinc.

While essential in small quantities, some of these metals are toxic if too much is present. Other metals, of which cadmium and mercury are prime examples, perform no known useful functions in plants or animals and are toxic at quite low concentrations.

The superphosphate used in Australia contains small quantities of many impurities besides cadmium. These include the six metals, listed above, added to cope with deficiencies in the soil. The amounts present are usually too small to have any noticeable effect, except in the case of zinc. CSIRO research in Western Australia has shown that the zinc impurity in superphosphate can supply a large part of the requirement of plants on zinc-deficient soils.

The other impurities in superphosphate seem to do no harm or good. Two major ones are iron and aluminium, but they are swamped by the large amounts of these metals already occurring naturally in the soil. Others include fluorine, and small quantities of strontium and uranium.