Pollution of crops and pastures by a smelter

The South Australian town of Port Pirie is dominated by a metal-refining complex, incorporating the world’s largest lead smelter. The complex almost holds another record: its 205-m-high chimney, completed last August, is the second-tallest man-made structure in Australia, surpassed only by a stack at Mt Isa.

The smelters refine lead and zinc from ore mined at Broken Hill. The smoke climbing the chimney contains traces of these heavy metals — and of other elements, such as cadmium, that occur in smaller amounts in the ore.

Nowadays these traces are very small, but from 1889, when the first smelter began operating, until 1925, when emissions were greatly reduced following a Royal Commission report, an enormous quantity — perhaps 40 000 tonnes — of potentially toxic metals belched out of the smelter’s chimney. What goes up must come down, and the metals eventually fell to earth, where they persist. At least 3400 sq km of land are contaminated by lead, and in 270 sq km the soil contains 10 or more times the general ‘background’ level of 10 parts per million (p.p.m.). Cadmium and zinc pollute similar areas. We know the concentrations of the contaminants in soil and vegetables (see Ecos 7). To what extent are cereals and pastures affected, and is the health of humans and livestock at risk? A team of researchers from the CSIRO

With increasing distance from the smelter, pollution falls to a ‘background’ level. Zinc is shown here; lead and cadmium curves are similar. Copper is a negligible component of smelter smoke.

Division of Soils has been tackling these questions. Mr Richard Merry, Dr Kevin Tiller, Mr Paul de Vries, and Dr Brian Cartwright took samples of wheat and pasture plants from sites at various distances from Port Pirie, including points on a line stretching more than 30 km south from the smelters. The scientists collected both grain and whole tops of wheat plants, as well as specimens of some 30 pasture species and samples of the soils in which all these plants grew.

They then analysed the plants and soils to find out how much lead, zinc, and cadmium these contained. As a check, they also measured the concentrations of metals that are very minor components of the smelter smoke, such as copper.

They found a good correlation between the degree of contamination of most plants and the contamination of the soils they grew in. The more cadmium that pollutes the ground, for example, the more there will be in a wheat stalk or a paddy melon leaf.

The farther the scientists travelled along their south-bound transect, the less contamination they found, until, about 35 km from the smelter, the pollutant concentrations had dropped to ‘background’ levels similar to those found elsewhere in the State.

The levels of heavy metals in wheat came well within the limits set by State health authorities. What’s more, the pollutant metals become diluted during bulk handling and milling, when contaminated grain is blended with wheat from unpolluted areas. The researchers believe that human health is unlikely to be endangered by the heavy metals in wheat grain harvested near the smelters.

The uptake of metals by plants

Heavy metal uptake is illustrated here by cadmium: the more there is in the soil, the more will contaminate a plant. Most pasture species take up less cadmium than Ward’s weed but more than bluebush. Soil metal values were obtained by extraction with a standard reagent, EDTA.

Smelter ‘fall-out’ landing on the leaves and stems of wheat plants did not apparently contribute to contamination, even in crops grown nearby. Washing wheat plants made no difference to their metal content; this was not surprising, as the concentrations of heavy metals in the fumes from the smelters have been kept very low for years.

Wind-blown soil dust could in theory contaminate plants, but wheat grain is well protected within the head as it develops, and the scientists found no evidence that dust had contributed to the higher levels of heavy metals found in grain grown near the smelters.

All this may come as a relief to local farmers, but what of the pastures that form an essential part of crop rotations? Around Port Pirie the main pasture species are annual medic and various annual grasses, with native chenopods (species of goosefoot) and introduced weeds. In places stock graze over former wheatlands that have reverted to saltbush and bluebush, or on samphire growing on salty soils.

Mr Merry and Dr Tiller, who carried out the study of pasture contamination, found that different plant species took up widely differing quantities of metal pollutants, and in different ways. Cadmium and zinc, it appears, are absorbed by the roots, but most of the lead is deposited on shoots, from dust and chimney fall-out. The scientists believe that soil dust plays little part in pasture pollution except within about 5–10 km of the smelters.

Ward’s weed recorded the highest cadmium and zinc concentrations, and potato weed topped the list for lead, with Ward’s weed not far behind. At the other end of the scale, the least-
contaminated plants were the species of bluebush. The scientists collected their samples at three times of year, and included plants at various stages of their life cycles, and this may at least partly account for the variations between species.

Sheep and cattle graze on these pastures; are they being harmed by their Saltbush is grazed on some former wheatlands.

chemical diet? This is a tough question. It seems that the risk depends to some extent on which species they eat. By choice, the stock take the main pasture plants, but when these are in short supply the animals turn to saltbush and bluebush, and finally the burrs (fruits) of medic.

In the semi-arid climate of Port Pirie, the growing season lasts for only 5 months and drought conditions occur frequently. This means that sheep are often driven to rummaging for medic burrs, inevitably garnished with a significant quantity of soil, which contains higher metal levels than do the plants. The animals’ intake of lead, in particular, will rise, since lead is about 10 times as concentrated in soil as in pasture.

Scientists do not know all the ways in which heavy metals may affect animals. Certainly too much of any one metal will be toxic. What’s more, some pollutant metals antagonize essential elements: for example, an animal that swallows some cadmium will absorb less of the copper in its food than if its meat had been unpolluted.

Ward’s weed, which was introduced from the Mediterranean region, contains relatively large amounts not only of cadmium but also of sulfur, another element that antagonizes copper.

The risk is particularly hard to assess because several metals are involved, and they interact. Zinc, for example, aggravates lead toxicity. On the other hand, calcium and phosphorus help to offset the toxic effects of both lead and zinc. The Port Pirie region has calcareous soils, which perhaps offer stock some measure of protection.

Bluebush is less contaminated than most plants examined, but stock turn to it only when the main pasture species are in short supply.

Animals vary in their physiological responses, too. Sheep and cattle tolerate lead in their diets at concentrations up to 300 p.p.m. without showing any ill effects, although they do accumulate the metal. (This concentration is many times higher than any the scientists found in plants near Port Pirie.) Other nonruminants cannot put up with lead levels nearly as high as this: horses, for example, can tolerate only about 80 p.p.m.

The scientists found lead concentrations of 2000 p.p.m. or even more in soils in the town, and wheat and pasture soils near Port Pirie often contained 300–500 p.p.m. Because the most contaminated soils grow the most contaminated vegetation, the researchers believe that the animals at greatest risk are those within about 5 km of the smelter complex.

Mr Merry and Dr Tiller feel that this question of animal health needs further investigation. A study being carried out at the Institute of Medical and Veterinary Science in Adelaide is providing valuable information. There, Mr Tee Siaw Koh and Dr Geoff Judson are testing the idea that the copper deficiency observed in sheep grazing near the smelters could be caused by the levels of heavy metals in the diet.

The scientists selected six properties from 6 to 40 km south of the smelters, and onto each farm moved 14 sheep from the State’s unpolluted south-east. Assisted by Mr Warwick Hack of the South Australian Department of Agriculture, they took samples of blood and faeces every 3 months, and every 6 months they killed three sheep on each property and removed liver, kidney, muscle, and bone samples.

The analyses show how much of the heavy metals the sheep are swallowing and absorbing into their tissues, and enable the researchers to keep an eye on the animals’ levels of copper and other essential elements. The faecal samples told a clear story of increased heavy metal intake near the smelters. Faeces from the sheep nearest Port Pirie contained 40 times as much lead as faeces from the sheep on the most distant property, where the animals were exposed only to ‘background’ levels of heavy metals. The corresponding ratio for cadmium was 30, and for zinc 4.

We must expect some of these additional heavy metals to find their way into the sheep’s organs. Mr Koh and Dr Judson have found three to five times as much lead and cadmium in the blood and tissues of the sheep near the smelters as in the ‘background’ sheep.

The sheep consuming the largest quantities of heavy metals also had the lowest concentrations of copper in their livers — only one-twentieth the “normal” value.

The scientists comment that the experimental sheep near the smelters might have approached or even reached a state of copper deficiency. The faecal analyses show that on all properties the sheep ingested the same amounts of copper, so it seems likely that the absorption of copper from the gut into the blood is impaired, probably by high levels of one or more of the heavy metals.

Clearly a question that will need answering is whether the metals accumulating in livestock raised near Port Pirie may, when the meat reaches the dinner table, present a hazard to human health.