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Keith Croker

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The accumulation and run-down of dieldrin in wethers grazed on paddocks previously treated with dieldrin

By Tony Albertsen, Research Officer, Bunbury; Roy Casey, Regional Veterinary Officer, Bunbury; and Keith Croker, Senior Research Officer, Sheep and Wool Branch, South Perth

In mid 1987, the organochlorines (O/Cs) DDT, dieldrin, heptachlor and chlordane were deregistered for agricultural and horticultural use in Australia. These chemicals had been used widely, and land on several hundred Western Australian farms, particularly where potatoes had been grown, was contaminated with chemical residues. Livestock grazing pastures on such land was also contaminated, and our beef exports were threatened.

In 1988, the Western Australian Department of Agriculture started a two-year project to collect information from sheep which were grazed on land that had previously been treated with O/Cs, particularly dieldrin. The levels of O/Cs in body and wool fats were monitored to obtain information on potential residues in export products.

Sheep grazed on dieldrin-contaminated land had body fat residue levels that paralleled the seasonal pasture levels of dieldrin. These levels increased during summer and especially in autumn, and decreased during winter and spring.

Wethers grazed on land with 0.4 parts per million (ppm) dieldrin in the soil had body fat levels that exceeded the maximum permissable concentration (MPC) of 0.2 ppm.

Their body fat residues increased with higher levels of soil contamination, especially on poorly structured (loose, dusty) soils. However, once stock were moved onto clean uncontaminated land their body fat levels of dieldrin almost halved every three weeks during the first three months they grazed clean land, until levels were below the MPC.

The average wool fat level of 0.6 ppm dieldrin was well below the critical level of 3.0 ppm (Table 1), even on soils which contained 1.3 ppm dieldrin.

Background

Organochlorine insecticides were used to protect the production of vegetables and fruit in particular, but also cereal and legume crops and pastures.

In soils O/Cs are strongly bound to the colloidal clay and organic soil fractions. Soil-bound O/C residues decontaminate naturally, mainly by vapour loss, but the breakdown rate is extremely slow. Significant O/C residues are present in soil decades after the last application of the O/C insecticides.

Table 1. Maximum tolerated residues of organochlorines (ppm)

<table>
<thead>
<tr>
<th>O/C</th>
<th>Soil</th>
<th>WADA standards</th>
<th>MPC sheep body fat</th>
<th>Industry (AWC) standard wool fat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dieldrin</td>
<td>Pasture</td>
<td>0.1</td>
<td>0.05</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.0</td>
</tr>
<tr>
<td>Heptachlor</td>
<td></td>
<td>0.1</td>
<td>0.05</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.0</td>
</tr>
<tr>
<td>Chlordane</td>
<td></td>
<td>0.1</td>
<td>0.05</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.0</td>
</tr>
<tr>
<td>DDT</td>
<td></td>
<td>0.1</td>
<td>0.05</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.0</td>
</tr>
<tr>
<td>Chlorpyriphos</td>
<td></td>
<td>0.1</td>
<td>0.05</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.0</td>
</tr>
<tr>
<td>WADA = Western Australian Department of Agriculture</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MPC = maximum permissable concentration</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AWC = Australian Wool Corporation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Soils containing O/Cs contaminate pastures and the ingestion of both the pasture and soil produces residues in animals. Plant and animal products are rejected by both domestic and export markets if the levels of O/Cs exceed the MPC.

In Western Australia, soils contaminated with O/Cs are mainly found in the higher rainfall areas of the south-west (more than 600 mm average annual rainfall). Land use options for contaminated paddocks in decreasing order of risk include: timber, fruit, vegetables, silage and hay, usually without accumulating unacceptable residues. Alternatively, farmers can graze sheep, beef or dairy cattle, but these choices are more risky and so the management strategies used must produce products that contain O/Cs at levels below the MPC.

Before the sheep monitoring project started, preliminary information came from a flock of Merino ewes agisted on a potato growing farm near Pemberton. Chlordane, dieldrin and heptachlor had accumulated in the body fat of pregnant ewes grazed during spring, summer and autumn and had reached concentrations above the MPCs of 0.2 ppm. Subsequently, the body fat levels of these O/Cs fell rapidly over the three months during which the ewes were lactating on land not previously treated with O/Cs.

The levels of dieldrin, heptachlor and chlordane did not exceed 0.6 ppm in the wool fats at any stage of the grazing. When grazing on the potato farm had finished the average level of DDT in the wool fat was above 2 ppm, a level of concern.

This investigation showed the potential hazard of grazing sheep on contaminated land before slaughter. However, there were several problems associated with the study because the ewes were rotated between paddocks which did not have large amounts of ground cover and they subsequently lambed and lactated after they were returned to the clean farm. The effect of these factors on the O/C levels could not be measured.

Consequently, a more detailed two-year investigation was started in June 1988. Mature aged (6-tooth) Merino wethers were set-stocked on eight sites already contaminated with dieldrin. The levels of dieldrin in the soils and pastures, and the amounts of pastures on offer, were measured. The levels of dieldrin in the body and wool fats were also measured to relate the levels of contamination of soil and pastures with the amounts accumulated in the sheep.

Details of the Merino wether study

Eight one-hectare sites, with a range of levels of dieldrin-contaminated soils, were selected on commercial farms in four of the Department's advisory districts in the south-west. The locations of the sites and the main features of each are shown in Table 2.

The position of each site within the paddock was determined from the O/C levels of 40 soil samples (0 to 10 cm depth) collected on a 20 m square grid pattern two months before grazing started.

In July 1988, each site was stocked with 10 mature aged Peppin Merino wethers (the 1988 main mob) with an extra 10 wethers (spring mob) being added in September to graze the
spring pasture flush. These additional sheep were removed in December 1988 and grazed on clean land at Vasse Research Station. No extra sheep were added to the plots for the 1989 spring flush (see Figure 1).

At the start of winter in 1989, the 1988 main mobs were split into two subgroups of five at each site. One subgroup (the 1989 main mob) was retained on the sites whereas the other subgroup (the 1989 run-down mob) was put onto clean country at Vasse Research Station at a comparable stocking rate. These wethers were replaced by another five wethers (1989 replacement mob) from the original population. The replacement wethers had been grazed on clean country and contained no dieldrin in their body or wool fats.

The wethers were weighed at the start of winter, spring, summer and autumn. Samples of body fat were then obtained under local anaesthetic from the brisket region of each wether and samples of wool were collected from the right side. Each sample was collected from a new site.

All the wethers were shorn in September 1988 and 1989. Other management aspects of the sheep were left to the collaborating farmers.

At each site at four-weekly intervals, the availability of pasture and the proportion of bare ground was recorded, and samples of pasture and soil were collected and analysed for O/Cs. The botanical composition and growth of the pastures were also recorded at four-week intervals but only during the growing season (up to December 1988 and from April to December 1989).

All samples of body and wool fats, soils and pastures were analysed for dieldrin at the Chemistry Centre of Western Australia.

The results from the first 15 months of the study are discussed here.

**Results and discussion**

The levels of O/Cs in the pastures depended mainly on the levels of soil contamination. Pasture contamination was also higher on soils with poor structure, because of the greater physical adsorption of soil-bound O/Cs direct onto the pasture from dust and mud splash.

### Table 2. Main features of each site used in the mature aged Merino wether study

<table>
<thead>
<tr>
<th>Location</th>
<th>Soil type</th>
<th>Dieldrin contamination(^1) (ppm)</th>
<th>Soil structure</th>
<th>General features</th>
<th>Pasture species</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>annual</td>
</tr>
<tr>
<td>Denmark</td>
<td>Loam</td>
<td>0.30</td>
<td>Good</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Brookhampton</td>
<td>Loam</td>
<td>0.36</td>
<td>Good</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Donnybrook</td>
<td>Loam</td>
<td>0.40</td>
<td>Good</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Jindong</td>
<td>Loam</td>
<td>0.43</td>
<td>Good</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Manjimup</td>
<td>Loam</td>
<td>0.47</td>
<td>Good</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Albany</td>
<td>Peat</td>
<td>0.79</td>
<td>Good</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Carbunup</td>
<td>Loam</td>
<td>0.87</td>
<td>Poor</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Pemberton</td>
<td>Loam</td>
<td>1.32</td>
<td>Good</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

Note: Soil dieldrin standard is 0.1 ppm.

\(^1\) The average dieldrin contamination over the 15 month period.
Soil type also influenced pasture levels of O/Cs. It appears that pastures grown on organic peat soils do not have the same level of contamination as those grown on loam soils with an equivalent soil contamination when measured at the standard 0 to 10 cm depth.

Pasture O/C levels were highest in newly germinated swards and progressively decreased as the pasture grew into winter. In spring pastures, the high growth rates result in tall, dense, bulky swards which effectively dilute the amount of O/C contamination in the pasture. The thin, trampled, dusty, dry pastures of late summer also can contain high levels of O/Cs.

In general, pastures based on annual species have plant O/C levels that increase in autumn and progressively decrease during winter and especially in spring. Plant O/C levels again increase over summer. Levels were higher in subterranean clover than in grasses or weed species at equivalent levels of soil contamination.

Pastures based on annual species had higher levels of contamination than those also containing perennial species. The organic thatch (stolons, runners and leaves) in swards containing perennial species acts as an insulating buffer between the primary source of contamination, the soil, and the grazed plant tops.

The seasonal body fat levels of O/C contamination in sheep generally paralleled those of the seasonal pasture levels. At moderate levels of soil contamination (less than 0.5 ppm dieldrin), the levels of O/Cs in the body fat of sheep increased during summer and especially in autumn, and decreased during winter and spring. At higher levels of potential soil contamination (more than 0.8 ppm dieldrin), body fat levels increased during summer, autumn and winter and decreased during spring.

During the first 15 months of grazing there was an overall net accumulation of dieldrin in the body fat of sheep.

Sheep body weights increased slightly in spring but remained relatively constant throughout the study. Therefore, liveweight, and presumably body composition, would have had little influence on the O/C levels detected.

Body fat levels can exceed the MPC of 0.2 ppm dieldrin on land contaminated at 0.43 ppm. At higher levels of potential soil contamination (1.33 ppm and 0.87 ppm with poor soil structure), the body fat levels of dieldrin can double and quadruple the MPC (Figure 2).

On loamy soils sheep body fat levels of dieldrin increased with increasing levels of soil contamination. However, on organic peat soils body fats were not contaminated to the same extent as on loam soils. The body fat from wethers grazed on the poorly structured loam soil contained higher levels of dieldrin than would be expected from the level of soil contamination.

Once stock were moved onto clean uncontaminated paddocks, the amount of dieldrin in the body fat fell rapidly, almost halving every
three weeks during the first three months they grazed clean land. This run-down was evident in wethers from all sites, both with the 1988 spring mob and particularly with the 1989 run-down mob. Figure 3 shows the results for wethers grazed on a loam soil at Jindong, but with the run-down mob grazed on clean land at Vasse.

The levels of dieldrin in the sheep only refer to the average concentrations. It is important to realize that there were large variations in the concentrations analyzed for individual sheep. However, body fat levels of dieldrin in all sheep can be reduced to below the 0.2 ppm MPC providing farmers have enough clean land and sufficient time to graze sheep before marketing. Even at moderate levels of soil contamination (less than 0.5 ppm dieldrin) body fat residues can fall below the MPC during the spring flush.

Wool fat levels of dieldrin increased progressively during the 15 months sheep were grazed on moderately contaminated loam soils (less than 0.5 ppm dieldrin). Only on soils with high levels of dieldrin and/or with poor structure did the rate of contamination of wool with dieldrin rise rapidly. The reason for this rapid increase is not clear but it may be related to soil adsorbed directly on to the fleece.

Within the first 15 months of exposure to dieldrin in the various locations examined in this study, the Australian Wool Corporation's 'industry standard' limit of 3.0 ppm dieldrin in wool was not exceeded, even on soils with a high potential for contamination (Figure 4).