ENVIRONMENTAL RESIDUES UNDER NEW ZEALAND CONDITIONS

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Summary

The use of organochlorine insecticides has been or is being phased out in many countries in favour of less persistent chemicals. While the contribution of organochlorines to public health and agriculture has never been seriously questioned, their future use must now be balanced against the known and the possible hazards resulting from their widespread distribution in the environment. Environmental residue data on DDT under New Zealand conditions of use are presented with comments on their significance.

INSECTICIDE TOXICOLOGY is a specialized branch of general toxicology and the principles followed in the investigation of poisons in general apply also to chemical insecticides. Essentially these are identification and measurement of the toxic agent and interpretation of the findings based on the case history. For example, finding DDT in tissues is proof only of exposure of an animal in some way to the insecticide but is not proof of any harm to the animal. Additional information is required on the source of the insecticide, the route, intensity and duration of exposure and, where mortality has occurred, a description of observed clinical symptoms. Data from previous similar cases assist in establishing a sound diagnosis. Where acute or sub-acute poisoning is involved, diagnosis is usually a simple matter of cause and effect. However, effects that may be caused by long-term exposure to low concentrations of persistent insecticides are often difficult to detect and to differentiate from natural causes of population fluctuations. Reduced viability of bird and fish eggs, impaired response of fish to temperature changes, and abnormal behaviour patterns in birds are some effects that have been ascribed to environmental exposure to insecticides. At Wallaceville we have examined birds and fish in cases of suspected insecticide poisoning but no insecticides have been detectable. On the other hand, we have found insecticides in birds and fish sampled from wildlife populations that were apparently normal and healthy. While scientists and laymen are understandably concerned with the continued use of persistent chemicals, the effects of these can be assessed only on the basis of continued research and this requires the combined services of the analyst, the biologist and the conservationist in the field.

In New Zealand, DDT has been the predominant agricultural pesticide during the past twenty years; lindane has had limited use on soils, on stock and in horticulture, while recent uses of the cyclodiene organochlorines have been confined to horticulture and non-grazing land. For most of this period, our analytical facilities have been concerned with residue studies on food crops, animal feedstuffs and produce derived from animals. However, in recent years we have accumulated data on a variety of species, either from specimens submitted in cases of sus-

pected poisoning or from limited samplings of wildlife populations. More comprehensive surveys on birds, fish, small and large mammals were begun this year and some of this information is available.

The highest concentrations of DDT found have been in orchard soils as the result of many years' accumulation of annual spray deposits (Table 1). No residues were found in soils from sheep and dairy farms on which DDT had never been used. Others contained up to 6.2 lb DDT/1 in. acre. It is now clear that topsoil is the major source of continuing DDT contamination in domestic stock and in many wildlife species. Thus, "background" residues in the fat of cows and sheep can be related to both the amount of DDT in topsoil and to the quantity of topsoil that they ingest with their feed (Table 2). Traces only of DDE are found in stock on farms where no DDT has been used. Residues of DDT, in birds that nested and fed predominantly in orchards, were much higher than in the same species sampled from non-orchard habitats (Table 3), and some deaths of blackbirds and thrushes were apparently a result of the high DDT/DDD content in the soil of a Christchurch orchard (Collett and Harrison, 1968).

TABLE 1: RESIDUAL DDT IN SOILS UNDER PASTURE

<i>Source of Soil</i>	<i>No. of Premises</i>	<i>Year Sampled</i>	<i>Total DDT, lb/3 in. acre Range</i>	<i>Mean</i>
Orchards:				
Hastings	19	1967	1.7-60.9	25.5
Nelson	6	1967	0.8-27.7	15.7
Central Otago	7	1967	2.0-27.9	10.0
Dairy farms:			<i>Total DDT, lb/1 in. acre</i>	
Hawera	6*	1968	1.2-4.6	2.4
		1969	0.8-2.2	1.4
Stratford	5*	1968	1.4-6.2	3.5
		1969	0.6-4.4	2.1
Te Puke	4*	1968	1.5-4.6	2.4
		1969	0.8-2.0	1.2
Tirau	4*	1968	1.0-4.0	2.7
		1969	1.0-2.9	1.4
Wairarapa	6*	1968	1.0-2.7	1.8
		1969	1.0-2.9	1.8
Ruakura	30 plots	1968	0.03-4.4	1.3
Sheep farms:				
Winchmore	18 plots	1967	0.7-4.6	2.8
Mid-Canterbury farm		1967	No DDT used	nil
Lincoln plots, cultivated		1967	Soil depth	
			(in.) 0-1	0.23
			1-2	0.24
			2-4	0.49
			4-6	0.52
			6-8	0.36
			Totals 0-8	1.84

*No DDT was applied on these 25 farms after 1967.

Earthworms, especially in uncultivated soils, play a vital role as soil conditioners. Fortunately, earthworms are largely unaffected by most pesticides (Edward, 1969) but they have the ability to accumulate DDT and similar compounds from their surroundings (Table 4). No DDT or its metabolic products were found in worms taken from farm paddocks on which DDT had never been used and such worms have been used safely for feeding kiwis in captivity (H. Turnbull, pers. comm.).

Much has been written about food chains and ecological magnification of organochlorines. That there are situations where this may occur in New Zealand can be deduced from the tables. For example, amongst the birds examined, carnivores and scavengers such as harrier hawks, shags and seagulls had higher residues (predominantly DDE) than the seed and plant feeders. Residues in lambs at the time they were weaned were about twice those in their dams although only the ewes had been exposed to DDT, the lambs having derived their DDT from the ewes via the milk (Table 2). Levels of total DDT in trout from landlocked lakes were higher than in fish from streams and coastal waters (Table 5). In the various lake-trout, the higher residues were associated with higher known usage of DDT on farms in catchment areas of the lakes. Hopkins *et al.* (1969) have provided evidence of a possible link between loss of reproductive potential and the level of DDT in parent female trout in Lake

TABLE 2: RESIDUES, DERIVED FROM SOIL, IN FAT SAMPLES FROM STOCK

		Description (DDT in soils expressed in lb total DDT/1 in. acre)	Total DDT in Fat (ppm)
Dairy cows:			
Hawera herds	(5)	Soil DDT — 1.84 lb (av.)	1.2
1968-1970		Soil in faeces — 17% (av.)	
Te Puke herds	(4)	Soil DDT — 1.80 lb (av.)	0.7
1968-1970		Soil in faeces — 6% (av.)	
Cambridge herd		DDT never used on farm	< 0.01
1970			
Sheep:			
Wallaceville hoggets	(26)	Soil DDT 0.05 lb	0.2
1965			
Winchmore hoggets	(80)	Soil DDT 2.8 lb	2.2
1967			
Lincoln hoggets			
1968			
Group 1	(8)	Soil DDT up to 0.03 lb	0.5
Group 2	(8)	Soil DDT up to 0.7 lb	1.0
Group 3	(8)	Soil DDT up to 3.7 lb	
Wallaceville trial			
1969			
Ewes	(4)	{ Control group: ewes only fed soil containing low residue of DDT	0.27
Lambs	(6)		0.80
Ewes	(3)	{ Dosed group: ewes only fed soil equivalent to 100 g/day, the soil containing 2 lb DDT/1 in. acre	1.23
Lambs	(3)		2.89

TABLE 3: RESIDUES IN BIRDS

<i>Sampled from general populations 1965-70</i>		<i>Mean Residues in Breast Muscle (ppm)</i>			
		<i>DDE</i>	<i>DDD</i>	<i>DDT</i>	<i>Total</i>
Starlings	(6)	—	—	—	nil
Wekas	(5)	—	—	—	nil
Pukeko	(1)	—	—	—	nil
Sparrows	(7)	0.03	—	—	0.03
Paradise ducks	(6)	0.11	0.05	0.02	0.18
Weka	(1)	0.30	—	—	0.30
Seagulls	(6)	1.1	—	—	1.1
Ducks	(3)	0.9	0.4	0.2	1.5
Shags	(5)	3.4	0.1	0.3	3.8
Harrier hawks	(6)	23.0	2.5	0.3	25.8
<i>From orchard habitats</i>					
Mynas	(10)	8.9	1.8	0.5	11.2
Thrushes	(5)	12.0	11.1	3.8	26.9
Blackbirds	(10)	20.1	16.2	2.8	39.1
<i>From non-orchard habitats</i>					
Mynas	(10)	0.7	0.1	—	0.8
Thrushes	(3)	0.2	Tr.	Tr.	0.2
Blackbirds	(3)	0.1	Tr.	—	0.1
<i>Diagnostic cases of suspected poisoning</i>					
Budgerigars	(2)	{Died after being fed with			272*
Finches	(4)	{DDT-contaminated birdseed			67*
Magpies	(4)	{Found dead following the use of DDT prills			19.4†
Stilts	(2)	{Found dead following the			10†
Seagulls	(1)	{use of DDT spray to control			13†
Ducks	(3)	{midges on estuary			44†
Blue heron	(1)	{			41†

*Residues mainly DDT; †Residues mainly DDE

TABLE 4: RESIDUES IN EARTHWORMS

<i>Source of Sample</i>	<i>Description</i>	<i>Residue in Whole Worms (ppm)</i>			
		<i>DDE</i>	<i>DDD</i>	<i>DDT</i>	<i>Total</i>
Christchurch orchard 1964/65/66	From soil containing	1.7	3.8	7.3	12.8
	15-20 lb DDT/6 in. acre	11.0	10.0	7.8	28.8
		2.3	2.6	8.5	13.4
Farm paddocks (4)	DDT never used	—	—	—	nil
Farm paddocks (2)	DDT used the previous year	0.24	0.08	0.74	1.06
	Pasture sown with DDT 5 years before	0.23	0.07	0.82	1.12

TABLE 5: RESIDUES IN FISH

Source	Date	Mean Residues in Flesh (ppm)			
		DDE	DDD	DDT	Total
<i>Rainbow trout from North Island lakes</i>					
Okataina	(12) 1964	0.16	0.04	0.24	0.45
Opouri	(12) 1964	0.27	0.17	0.04	0.47
Rerewhakaaitu	(12) 1964	0.28	0.34	0.17	0.92
Okataina	(10) 1966	0.08	0.02	0.04	0.14
Waikaremoana	(10) 1966	0.10	0.01	0.05	0.16
Rotorua	(10) 1966	0.10	0.05	0.05	0.20
Taupo	(10) 1966	0.21	0.03	0.12	0.36
Rerewhakaaitu	(10) 1966	0.61	0.42	0.09	1.12*
<i>Sampled from streams and coastal waters (1969-70)</i>					
Crayfish	(6) Wairarapa coast	Tr.	—	—	Tr.
Eels	(5) Chatham Islands	0.01	—	—	0.01
Trout, young	(4) Christchurch	0.03	—	—	0.03
Flounders	(10) L. Ellesmere	0.02	Tr.	0.01	0.03
Eels	(10) Wainuiomata	0.03	Tr.	0.01	0.04
Groper	(11) Cape Kidnappers	0.04	—	—	0.04
Trout, adult	(9) Christchurch	0.07	—	—	0.07
Eels	(10) L. Ellesmere	0.05	0.02	0.04	0.11

*Eggs from these trout showed some loss of viability.

Rerewhakaaitu. In our experience, the concentration of DDT in natural waters would rarely exceed 0.00002 ppm so it is clear that fish, like earthworms, have the ability to accumulate DDT from their environment.

Residues found in wildlife species comprise mostly DDE and it is known that DDE is more cumulative and more persistent than DDT or DDD as well as being a normal metabolite of DDT. An incremental build-up, especially of DDE, in successive steps along natural food chains can therefore be expected. While DDE is less acutely toxic than DDT, there is experimental evidence that DDE can be harmful to ducks and pigeons (Heath, *et al.*, 1969; Bailey *et al.*, 1969) but only at much higher levels than would be expected in a natural environment.

Included in Table 3 are tissue residues for budgerigars and finches that died with typical symptoms after they had been given birdseed accidentally contaminated with DDT. The magpies were found dead on a paddock after it had been topdressed with DDT prills, and the ducks, stilts, seagulls and a blue heron were picked up near an estuary that had been sprayed with DDT to control midges. Although facilities for analysis in cases of this kind have always been available, very few cases involving organochlorines have been brought to our attention over the past twenty years. Considering the vigilance of wildlife and acclimatization society officers, and the interest of the general public in insecticides, it must be concluded that occurrences of this type have been rare during this period of extensive DDT use.

Analyses of wild deer, goats and pigs have revealed only traces of DDE in their body fat although few specimens have been tested up till now (Table 6). These findings are, however, consistent with the fact that the habitats of these animals in New Zealand would not normally be expected to contain much of any type of insecticide.

TABLE 6: RESIDUES IN LARGE MAMMALS

Species	No. tested	Mean Residue in Body Fat (ppm)			
		DDE	DDD	DDT	Total
Deer	17	< 0.01	—	—	< 0.01
Goats	5	0.03	—	—	0.03
Pigs	8	0.25	0.01	0.04	0.33

Recently the use of DDT on farmland has been prohibited in this country. Obviously, DDT will not disappear from the soil overnight, nor will the associated residue problems. As far as domestic stock are concerned, contamination of animal fats through topsoil ingestion should decrease with the natural depletion of residues in the soil (Table 1 compares residues in dairy farm soils for 1968 and 1969). Where there is a high concentration of DDT in the top soil, it has been suggested that residue risks to grazing stock could be reduced considerably by ploughing and resowing to pasture (Harrison *et al.*, 1969). Residues in the Lincoln plots for instance (Table 1) show that deep cultivation could reduce topsoil residues about eight times. Changes in residue concentrations in wildlife populations resulting from the prohibition of DDT use on farms would be difficult to predict and it would be wiser to obtain this information by continuing our current surveys during the DDT "run-down" period.

CONCLUSIONS

Most wildlife specimens were sampled during the past five years corresponding to the last quarter of a twenty-year period of continuous and widespread use of DDT, and it is probable that by now DDT equilibrium would have become established in most wildlife situations. The residues reported represent the net differences between intake and excretion at the time of sampling. As excretion, particularly of DDE, is relatively slow, it seems reasonable to conclude that present levels of DDT intake are low and that further controlled use of DDT would not result in further significant build-up of DDT in the total environment. There are some chronic hazards from DDT to fish and birds in specific localities such as inland lakes and orchards, and there have been isolated cases of acute DDT poisoning in birds from DDT prills, dusts and sprays. Monitoring of residues in domestic stock and wildlife species is to be continued to provide environmental data during the next few years of the post-DDT era.

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