DDT Residues in Forest Soils

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Large tracts of forest in eastern North America have been sprayed repeatedly with DDT during the past 20 years to help protect this valuable resource from damage by various insect pests. Although in recent years DDT has been largely replaced for this purpose by more selective and less persistent chemicals(1), accumulated residues of DDT persist in forest soils and their presence and possible biological effects are cause for concern to ecologists. This is a preliminary report on forms, amounts and distributions of DDT in the forest soils of New Brunswick (N.B.), together with results of toxicological tests with these soils which will help to clarify the ecological status of this form of environmental contamination. A full description of the work will be published elsewhere, to include details of sampling and analytical methods, and statistics.

Soil samples were sieved and extracted in a moist state with a mixture of 2 parts n-hexane, 1 part acetone (redistilled) (2). Extracts were "cleaned-up" with florisil and analysed by gas (3) and thin-layer (4) chromatographic techniques. Insect bioassays were made by comparing mortalities produced in populations of Drosophila (5) using DDT standards, with those produced by aliquots of contaminated forest soils (6).

A 1000 acre plot of mixed forest land was reserved in 1967 for ecological studies of pesticides in the forest environment at Priceville, in central N.B. This study plot was selected to represent a much larger surrounding area which had, in total, 70 ounces per acre technical DDT applied by aircraft for Spruce budworm (Choristoneura fumiferana Clemens) control during the previous 11 years (7). When this present study was begun at Priceville in 1967, the only information available on DDT residues in the soils of N.B. forests was that published by Woodwell (8,9) for a locality at Budworm City (B.C.) in northern N.B. The analyses of Priceville soils (Table 1) showed smaller residues of DDT and different isomer compositions from those given by Woodwell for B.C. soils, although Priceville was recorded as having received heavier

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TABLE 1

Comparison of DDT residue estimates and isomer compositions for two locations in New Brunswick, according to different authorities

Location and date	DDT residue (upper, oz./acre: lower, % composition) pp' DDT	op' DDT	pp' DDE	pp' DDD	Total DDT	Reference
Budworm City 1958	2.56 35	4.80 65	- 0	- 0	7.36	9
1960	11.04 41	15.84 59	- 0	- 0	26.88	*
1961	9.76 34	19.36 66	- 0	- 0	29.12	*
1967	9.48 70	2.16 16	1.90 14	trace trace	13.54	Yule **
Priceville 1967-68	9.64 85	0.91 8	0.80 7	trace trace	11.34	Yule ***
Average formulation composition	70-80	20-30	trace	trace	+ traces of others	15
1967 formulation used in New Brunswick	77	21	2	trace		Yule

*(9) Stand I - Total DDT reported as applied 64 oz./acre, from 1952-58.
** Stand I - Average of 3 samples.
*** Average of 44 samples, DDT applied 70 oz./acre from 1956-67.
Yule reference to present work.

and more recent application of DDT than the B.C. site. To resolve this apparent difference, samples of soil were taken in 1967 from exactly the same location at B.C. as used by Woodwell (I in 8 & 9) and analysed by the chromatographic techniques outlined above. These results confirmed Woodwell's and our own Priceville findings that DDT residues were present only in the top few inches of soil. Most of the residues both at B.C. and Priceville occurred as the pp' form (70-85%), some of the pp' DDT had apparently been changed to DDE in the soil, and a loss of op' DDT had occurred (as yet unaccounted for, but not leached, and no op' DDE was evident) compared to formulation compositions of the technical DDT applied (Table 1).

Spray programme veterans claim that Woodwell's sampling site near B.C. airstrip was heavily dosed with DDT by aircraft during local testing and calibration of spray equipment, and the relatively large amounts of DDT residue found there (Table 1) do not represent typical operational conditions. The error in op' DDT identification or measurement that is apparent in Woodwell's results (Table 1) is possibly due to the less discriminating colorimetric analysis used in that work. Our data show Woodwell's hypothesis of differential weathering and preferential retention of the op' DDT form by forest soils to be untenable, at least for the particular sites that have been examined. The difference in isomer compositions of B.C. and Priceville residues shown by our own analyses (Table 1) is likely to be a time-soil/breakdown-loss function, but could also be a reflection of differences in the composition of DDT technical formulations used in the early 1950's.

To obtain an index of ecological significance of the relatively high concentrations of DDT found in the litter layers of Priceville soils (4-20 ppm), contact-toxicity bioassays were made with Drosophila on the same profile horizon samples that were analysed chemically. The results obtained with surface soils taken from three sub-plots representing the three main forest (litter) types (softwood, hardwood, and mixed) at Priceville, are given in Table 2. The sour, highly-organic forest topsoils apparently "bind, mask" or make DDT residues unavailable to poison exposed insects, as has been shown by Harris (10) to occur in agricultural clays and mucks. The degree of "masking" appears to be influenced by the forest type determining the litter composition, masking being greatest with softwoods (balsam, fir, spruce), and least with hardwood litters (beech, birch and maple).

TABLE 2

Direct toxicity tests with *Drosophila* of Priceville surface soils (litter layer), compared with DDT standard toxicity (range in duplicate tests).

Material	Conditions (3reps. of 48-hour flies)	Results 72-hour % mortalities	A Mortality equivalent standard DDT (µg)	B Calculated total soil DDT from chemical analysis (µg/5g.)	B/A Soil masking factor
Standard (DDT 77% pp')	Dry-film in vial	50	0.50-0.55		
Plot I litter	5g. moist soil	15-17	0.22-0.25	22.45	89-102
Plot II litter	in Petri	18-21	0.26-0.28	64.25	229-247
Plot III litter	dish	80-87	1.00-1.10	53.80	49-54

I Soft and hardwoods mixed
II Mainly softwoods
III Mainly hardwoods

Thus, although DDT persists in Priceville soils mainly in the form of the most toxic isomer (pp' DDT), in considerable quantities (11 oz/acre), and mostly in the little layer where it is readily available to surface-dwelling organisms, the direct toxic effects of these residues are greatly attenuated by the soil itself. Consequently, their direct ecological significance is very much less than chemical analysis alone might indicate.

Another index of biological availability of residual DDT in the soil was obtained by analysing the whole bodies of surface-dwelling insects and spiders caught in pitfall traps (11) that were distributed

throughout the three sub-plots at Priceville. Surface-dwelling insects and spiders from each plot (no earthworms) contained more DDT than the average (6-inch) content in their topsoil habitat, but generally less than in the litter layer only. Apparently, due to soil-attenuation of the availability and direct toxic effect of surface residues of DDT, possibly augmented by long-term selection of DDT-tolerance in the soil fauna (12,13), primary food-chain organisms can survive and do actually accumulate relatively large amounts of DDT which may then be concentrated in passage to animals at higher trophic levels in the ecosystem (e.g. shrews, birds, predators) (14).

It is hoped that this information on DDT in soil will make a firm foundation for further ecological research on residue effects in the forest environment.

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