

Persistence of Some Chemicals in Pacific
Northwest Forests, Robert F. Tarrant

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PERSISTENCE OF SOME CHEMICALS IN PACIFIC NORTHWEST FORESTS

Introduction

"Persistence" is the tendency of a chemical compound to remain in an unaltered form. Results of research on persistence of DDT, phorate, and a number of herbicides indicate that environmental factors, characteristics of application method and rate, and nature of the chemical used are all important factors in determining length of persistence. Persistence of a given chemical cannot be assumed for one area on the basis of results from use in dissimilar localities.

In a paper included in the proceedings of this course, Norris (7) defined "persistence" as the tendency of a chemical compound to remain in an unaltered form. He also covered in some detail the various factors which determine persistence.

In this presentation I will summarize observations of persistence of several insecticides and herbicides used operationally in Pacific Northwest forests. Results of these field and laboratory studies are most valuable in assessing the environmental effects of economic chemicals used to increase forest production.

Persistence of Two Insecticides in Oregon Forests

DDT

The largest all-helicopter insect spray project ever conducted by the U.S. Forest Service was carried out between June 10 and July 1, 1965, in eastern Oregon. To control a serious outbreak of the Douglas-fir tussock moth (*Hemerocampa pseudotsugata* McD.), 66,000 acres of forest were sprayed with DDT at the rate of 12 ounces per acre.

Since shortly before the spraying, we have studied persistence of the aerially applied DDT in the forest floor and soil (11). A very small amount (0.13 ppm) of "apparent" DDT was found in prespray samples of the forest floor (Table 1). One month after spraying, concentration of DDT in the forest floor was slightly more than 7.5 ppm. Based on weight of the

Table 1. — Concentration of total DDT in the forest floor before and after aerial spraying.

Months After Spraying	Total DDT (ppm)
0	0.130
1	7.540
12	5.437
24	4.412
36	3.324

forest floor, this concentration amounted to 3.08 ounces per acre. Thus, about 26 percent of the intended DDT application of 12 ounces per acre reached the forest floor shortly after spraying.

DDT in the forest floor decreased steadily with time. At the end of the third year after spraying, more than half the DDT originally added to the forest floor had disappeared. Mechanisms of removal of DDT from the forest floor may include volatilization, chemical or photochemical degradation, or bacterial decomposition.

DDT did not leach from the forest floor to underlying soil (Table 2). Concentration of apparent DDT in prespray samples was 0.006 ppm at the

Table 2. — Concentration of total DDT in surface soil before and after aerial spraying.

Months After Spraying		Total DDT (ppm)
	<i>0-3-inch depth</i>	
0		0.006
1		.006
12		.029
24		.012
36		.006
	<i>3-6-inch depth</i>	
0		.002
1		.002
12		.006
24		.003
36		.002

0-3-inch depth and about 0.002 ppm at 3-6 inches. One month after spraying, these DDT levels had not changed, indicating that the forest floor effectively intercepted the spray solution. One year after spraying, DDT in the surface soil was at 0.029 ppm and in the lower soil, 0.006 ppm. This small increase is attributed to the physical action of soil animals and, most probably, to minor, unavoidable contamination during sampling. DDT has a solubility in water of only about 1 ppm (2, 8, 9).

At the end of the second year, DDT had decreased to 0.012 and 0.003 ppm, respectively, in the upper and lower soil depths. By the end of 3 years, DDT in mineral soil was at prespray levels.

DDT concentration in litterfall decreased with time at a greater rate than it did in the forest floor and soil (Table 3). Photochemical decomposition and volatilization may be effective mechanisms of chemical degradation in tree canopies exposed to sunlight. DDT concentration is also reduced in successive litterfall samples because of the constantly decreasing proportion of needles and twigs originally subjected to the spray.

Table 3. — Concentration of total DDT added to the forest floor in litterfall after aerial spraying.

Months After Spraying	Total DDT (ppm)
0-6	11.32
7-12	10.32
13-18	7.12
19-24	7.49
25-30	3.92
31-36	3.08

The input of DDT to the forest floor from litterfall after spraying did not contribute strongly to total amount observed. Total loss of DDT from the forest floor over 3 years amounted to 2.46 ounces per acre, more than three times the amount brought down in litterfall over the same period.

Additions of DDT to the forest floor by throughfall precipitation were insignificant—0.02 ounce per acre for the 3-year period following application. Concentrations varied with season (summer-fall vs. winter-

spring) and, in general, showed a gradual decrease with time (Table 4). DDT concentrations in samples representing the dry summer and fall months were approximately three times greater than those for the wet winter-spring season. Precipitation samples for the 12- to 18-month period after treatment contained higher DDT concentrations than expected relative to the amount of rainfall for the period and the concentrations found at 6 and 30 months. However, the DDT levels, their seasonal variations, and the total range in concentrations found in this study are consistent with normal climatological variations and similar to those reported for other regions (1, 10, 13).

Table 4. — Concentration of total DDT added to the forest floor in throughfall precipitation after aerial spraying.

Months After Spraying	Total DDT Residue (ppb)
0-6	0.176
7-12	.075
13-18	.364
19-24	.066
25-30	.103
31-36	.036

At the end of 3 years, DDT concentrations in throughfall precipitation had decreased appreciably but still were five to 10 times greater than levels found in samples from an untreated forested area in western Oregon (unpublished data). But the total amount of DDT brought down over this period in throughfall precipitation is infinitesimal compared with that part of the intended application that initially reached the forest floor or was deposited in litterfall. Thus, throughfall precipitation was not a significant factor in determining the fate of applied DDT or in maintaining DDT concentrations in the forest floor.

Of a total aerial application of 12 ounces of DDT per acre, 26 percent reached the forest floor initially, 6 percent was brought to the forest floor in litterfall over a 3-year period, and a fraction of 1 percent of the total was washed from the tree canopy over 3 years (Table 5). Thus, about one-third of the total application reached the forest floor.

In Arizona, less than 50 percent of insecticides aerially applied during the summer months was deposited on-target in agricultural spraying. The

Table 5. — Total DDT deposited on the ground surface (forest floor) over 3 years after aerially spraying DDT at 12 ounces per acre.

Source of DDT at Ground Surface	Total DDT	
	Ounces per acre	Percent of Total Applied
Initial deposit	3.08	25.66
Total deposit over 3 years from:		
Litterfall	.74	6.17
Throughfall precipitation	.02	.01
Total, all sources	3.84	31.84

distance from the spray aircraft to the target was shown to be inversely correlated with amount of on-target chemical application (12). Aircraft spraying forest lands must fly at far greater heights than those operating over level agricultural fields. Thus, the comparatively high amount of DDT reaching the forest floor is not surprising. This finding reaffirms that efficient methods of aerial spraying must be developed if we are to avoid undue loss of chemical to nontarget areas.

PHORATE

Phorate (Thimet) is a highly toxic systemic organophosphate insecticide used heavily in cotton production and also on some truck crops in southwestern United States. This chemical controls insects on cotton for up to 5 months, but residues in soil have disappeared long before harvest. Climatic conditions in southwestern United States, of course, are greatly different from those in the Douglas fir region of the Pacific Northwest.

Phorate was applied broadcast on the forest floor at rates of 1, 10, and 100 pounds per acre in a stand of young Pacific silver fir at each of two western Oregon locations in May 1966 (3). Persistence of phorate and its metabolites (measured as phosphorothiolate sulfone) was determined at the end of each of the first two growing seasons after application. The purpose of this experiment was to determine whether phorate would protect young trees against aphids and whether residue persistence was similar to that in warmer climates.

Mean concentrations in the forest floor after 6 months were 2.04-, 0.58-, and 631-ppm phorate and 2.78-, 26.56-, and 238-ppm metabolite for the 1-, 10-, and 100-pound-per-acre rates, respectively. Complete degradation was quite rapid at the two lower rates as indicated by total

residues of 8.40 and 9.98 percent of chemical applied for the forest floor and surface 12 inches of soil combined. At the 100-pound rate, however, 98 percent of the total chemical applied was still present in the forest floor and soil as phorate or its metabolites. Some downward movement had taken place, but less than 4 percent of the total residue was found below the 3-inch soil depth. After 18 months, measurable levels of both phorate and its metabolites were still present in the forest floor and soil. At the highest rate of application, the mean total residue was 4.50 pounds per acre.

This study shows again that we cannot predict the behavior and persistence of an economic chemical in a forest situation from previous experience under agricultural conditions. Residues in this forest study persisted beyond the first growing season probably due to a combination of factors. During the summer months, microbial activity is low because of dry conditions in the forest soil. Chemical degradation did take place at lower rates, but the highest rate of chemical applied was sufficiently toxic essentially to stop the already low level of microbial metabolic activity. By the time the soil moisture supply increased with fall rains, soil temperatures had already dropped to less than optimum and microbial activity remained low until the following spring.

Persistence of Herbicides

Four herbicides are commonly used in the Pacific Northwest to control unwanted vegetation: 2,4-D, amitrole, 2,4,5-T, and picloram. These chemicals are listed in order of persistence. All of them are degraded in the forest floor but at different rates (6).

In red alder forest litter, 2,4-D degrades most rapidly of all (Figure 1). In laboratory studies, after 35 days' incubation, only 6 percent remained of a total application of 2,4-D at the rate of 2 pounds per acre and only 5 percent remained of a 4-pound-per-acre application. The rate of 2,4-D degradation is slowed somewhat when either 2,4,5-T or picloram is applied with 2,4-D, but after 35 days, total degradation is the same as for 2,4-D alone.

Amitrole also degrades rapidly. After 35 days' incubation, only 20 percent of a 2-pound-per-acre application of amitrole remained in forest floor material. Persistence of amitrole was not affected when 2,4-D was applied concurrently.

Degradation of 2,4,5-T is somewhat slower than that of 2,4-D or amitrole, but after 120 days, only 13 percent of a 2-pound-per-acre application and 18 percent of a 4-pound-per-acre application remained in red alder forest floor material.

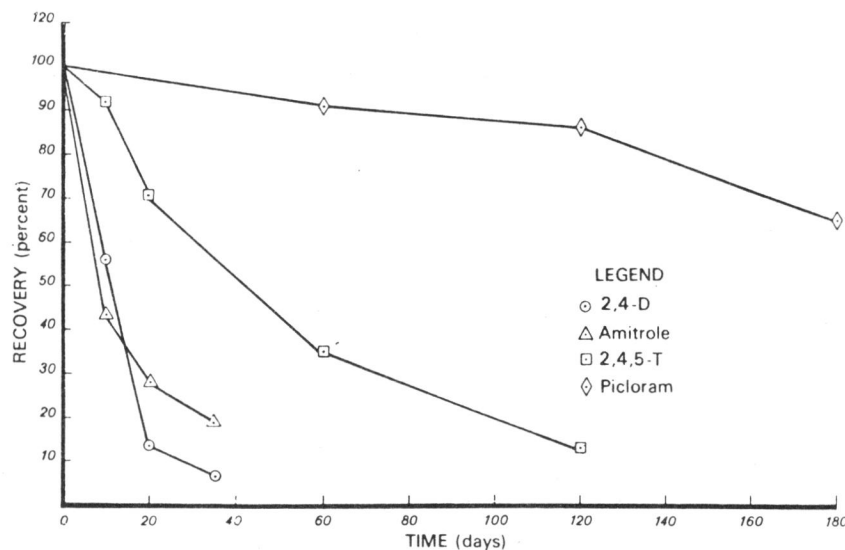


Figure 1. — Recovery of 2,4-D, 2,4,5-T, amitrole, and picloram from red alder forest floor material. Source: Norris 1970(a).

Picloram (trademark Tordon) is a relatively new herbicide of considerable potential use in controlling unwanted vegetation. It is normally applied at a lower rate than 2,4-D or 2,4,5-T but frequently in combination with them. When picloram was applied at 0.5 pound per acre with and without 2,4-D at 2 pounds per acre, there was no significant difference in persistence of picloram (6). After 180 days, however, more than 60 percent of the initial application of picloram remained in the forest floor.

Results of these laboratory studies have been confirmed by field studies of operational spraying. A number of monitoring observations in western Oregon and Washington have indicated that when forest lands are sprayed with herbicides during the spring growing season measurable quantities of herbicides are not present in streamwater during the first fall rains. Such rains did not introduce measurable amounts of herbicides in the streams flowing through the small scattered treatment units resulting from operational vegetational control measures. These findings are true for 2,4-D, 2,4,5-T, and amitrole. Even in cases where a fairly large proportion of a single watershed is treated with herbicides and where the treatment unit is oriented for a considerable distance along the stream, no measurable amount of herbicide was found after the first fall rains (4). Thus, unless a heavy application of chemical is made directly into the stream, the major potential for stream contamination from herbicide use

in the forest is from heavy rain or soil movement resulting in overland flow of water and sediment shortly after application. Such conditions occur only rarely.

Picloram is sometimes applied with phenoxy herbicides in the summer for brush control on powerline rights-of-way over forest lands. The effect of such summertime spraying on streamwater quality after the first few fall storms has been studied.

Runoff of picloram and phenoxy herbicides can occur after the first heavy autumn rains if the chemicals are applied in mid- or late summer. The greatest potential for herbicide runoff appears when early fall storms are sufficiently intense to cause overland flow rather than infiltration of water. The resulting amount of stream contamination is determined largely by the proportion of the watershed that is treated (5). In our studies, contamination was very low—a maximum of 6 ppb was found in only one sample.

Summary

In an eastern Oregon forest, more than half of the DDT originally reaching the forest floor after aerial spraying had disappeared at the end of the first 3 years after spraying. None of the applied DDT was present in the mineral soil at the end of 3 years.

Under western Oregon conditions, residues of the highly toxic systemic organophosphate insecticide phorate degraded quite rapidly when application rate was either 1 or 10 pounds per acre. However, at an application rate of 100 pounds per acre, about 98 percent of the chemical was still present in the forest floor and soil after 6 months. At the 100-pound-per-acre rate, a total residue of 4.50 pounds per acre was still present after 18 months. Findings from this study under forest conditions are entirely at variance with those for the same chemical used on agricultural crops in a warmer climate.

Of four herbicides studied, 2,4-D degrades most rapidly. Amitrole also degrades rapidly, but 2,4,5-T and picloram are of somewhat longer persistence. Studies of streamwater following first rains after application of these chemicals indicate, however, that 2,4-D, 2,4,5-T, and amitrole residues are not available for transport to streamwater after having weathered over one summer.

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