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THE BEHAVIOR OF 2,4,5-T AND TCDD IN THE ENVIRONMENT

Logan A. Norris

Research Project Leader, Pacific Northwest Forest & Range Experiment Station

Forestry Sciences Laboratory, Corvallis, Oregon

An adequate assessment of the toxicological hazards which may be associated with the use of 2,4,5-T requires a consideration of two things:

1. The toxicity of 2,4,5-T and its contaminant TCDD, and

2. The probability that nontarget organisms will be exposed to a biologically significant dose (Norris 1971).

This paper deals with the exposure organisms are likely to receive as a result of the operational use of 2,4,5-T in forest and rangelands. The following paper by Schwetz evaluates the toxicity of 2,4,5-T and TCDD.

The exposure organisms receive in the field is determined by the behavior of 2,4,5-T and TCDD in the environment. The behavior of these compounds is defined as their movement, persistence, and fate. Characterization of their behavior establishes how much chemical is in what part of the environment, for what period of time, and in what form. These define the magnitude, frequency, and duration of exposure. Whether or not the registered uses of 2,4,5-T result in a significant toxicological hazard to nontarget organisms is evaluated by comparing these characteristics of exposure with what is known of the toxicology of 2,4,5-T and TCDD.

The application of 2,4,5-T in forest and rangelands results in the initial distribution of the herbicide and its contaminant into the four major compartments of the environment: the air, vegetation, soil, and water. There is relatively little quantitative data on either compound in air. The chemistry of both compounds, however, suggests photodegradation will be rapid. The large dilution potential of the atmosphere offers an additional safeguard. The loss of spray material to the air can be minimized by proper selection of formulation and equipment operation and atmospheric conditions at the time of application.

BEHAVIOR OF 2,4,5-T IN THE ENVIRONMENT

The exposure of nontarget terrestrial organisms to 2,4,5-T is most likely to result from consumption or contact with recently treated vegetation. Residues of 2,4,5-T on vegetation are highest immediately after application. In a Pacific Northwest forest, 2,4,5-T residues were about 50 parts per million immediately after a 2.24 kg/ha application (Norris et al. 1977). Residues declined more than 90% in 1 month (table 1). Herbicide residues on vegetation are reduced primarily by metabolism, degradation, and weathering. Maximum opportunities for organism exposure obviously occur immediately after application. Declining residue levels and reduced palatability of susceptible treated vegetation prevents significant chronic exposure to 2,4,5-T.

Table 1.--Residues of 2,4,5-T in the forest after aerial application of 2.24 kg/ha (Norris et al 1977).

Time after application	Vegetation	Forest floor	Soil, 0-15 cm
(months)	(mg/kg)[1/]	(mg/m^2)	(mg/kg)[1/]
0	52.4	35.7	0.01
1	3.14	40.6	0.02
3	0.33	13.1	0.08
6	0.23	3.92	0.02
12	0.21	1.73	<0.01
24	<0.02	0.68	<0.01

[1/] ppm

Herbicide residues in forest floor are highest 1 month after application and then decline sharply (table 1). A combination of rapid degradation and extensive adsorption nearly eliminate the transfer of 2,4,5-T from the forest floor to the underlying soil. The maximum residues in soil (table 1) are equivalent to 8% of the original rate of application. 2,4,5-T persistence in the soil is brief and adsorption is extensive. These factors prevent

contamination of ground water by 2,4,5-T leaching through the soil profile.

Research and monitoring have consistently shown the primary and nearly exclusive source of 2,4,5-T in streamwater is direct application or drift of spray materials to stream channels (Norris 1967). The maximum concentration of herbicide occurs during and immediately after application. Concentrations as high as 90 parts per billion (ppb) have been measured, but usually levels in excess of 10 ppb are seldom encountered. Most water samples collected during operational aerial applications do not contain detectable (less than 1 ppb) residues of 2,4,5-T. Residue levels decline rapidly with time. Dilution, degradation, and adsorption processes reduce the concentration of herbicide in streamwater to below detectable levels within a short distance downstream from treated areas. Measurable residues of 2,4,5-T are rarely found for more than a few hours after application. Overland flow of 2,4,5-T on most forest areas does not usually occur because infiltration capacities far exceed rates of precipitation. Areas of compacted soil or locations where brief high intensity rainstorms occur may be exceptions.

BEHAVIOR OF TCDD IN THE ENVIRONMENT

TCDD is produced as a byproduct during one of the manufacturing steps of 2,4,5-T. TCDD is present in extremely low concentrations in the herbicide (less than 0.1 ppm), but is of substantial interest because it is highly toxic (Schwetz et al. 1973). The chemical, physical, and biological properties of TCDD have been investigated and a number of laboratory studies conducted to determine TCDD behavior (Lucier 1973). There is only a limited amount of data on the behavior of TCDD in the field.

The extremely small quantities of TCDD which are likely to be present in environmental samples has forced the development of the most rigorous and sensitive analytical methodologies yet developed for chemicals in the environment (Hummel 1977). These methods are now yielding data that will be of substantial value in establishing the degree to which theoretical and laboratory studies predict the environmental behavior of TCDD.

Kearney and associates conducted several laboratory experiments to determine the behavior of TCDD in plants and soil. Isensee and Jones (1971) reported small quantities of TCDD were accumulated by young oats and soybeans grown on a sandy loam contaminated with very high levels of TCDD. Mature plants or seeds on the other hand grown in the same soil did not contain detectable levels of TCDD. TCDD was not translocated from the point of application on the leaf surface to other plant parts. Some washoff and possible volatilization did occur. Crosby et al. (1971) showed that TCDD in pure form is not photodecomposed at a significant rate on wet or dry surfaces. Kearney et al. (1972) reported TCDD had a half life of approximately 1 year in soil in the laboratory.

These findings suggested TCDD was persistent in the environment, but this conclusion is not consistent with research done with TCDD in formulated herbicide in the field. Getzendaner and Hummel (1975, personal communication) and Crosby and Wong (1977) analyzed for TCDD on vegetation sprayed with 2,4,5-T and exposed to sunlight. Each group found TCDD disappeared rapidly. Crosby and Wong (1977) reported a half life for TCDD on vegetation of 1 to 2 hours. TCDD sprayed with herbicide on soil and exposed to sunlight showed a 15% decrease in 6 hours. This suggests a half life for TCDD on soil of approximately 50 hours. Shielding TCDD from sunlight by shading or incorporating into the soil will undoubtedly reduce the rate at which TCDD is photodecomposed. The effects of shading and reduced light levels remain to be established.

TCDD is virtually immobile in soil (Helling 1971). It is tightly bound by soil particles and has a low water solubility (0.2 ppb). This means leaching of TCDD and contamination of underground water supplies is unlikely (Kearney et al. 1973). The actual levels of TCDD in forest vegetation, forest floor, soil, and water have not been measured. They can be estimated however from initial residue levels of 2,4,5-T (assuming 2,4,5-T contains 0.1 ppm TCDD) and from TCDD persistence studies of Crosby and Wong (1977), Kearney et al. (1973), and Miller et al. (1973) (table 2). Verification of these calculated values is needed from actual residue studies.

Table 2.--Calculated residues of TCDD in the forest.

Time after application (weeks)	Vegetation (ng/kg)[1/]	Forest Floor (ng/m^2)	Soil (ng/kg X 10^3)[1/]	Water (ng/l X 10^4)[1/]
0[2/]	5	4	1	1
1	0.001[3/]	0.5[3/]	1[4/]	0.001[5/]
4	--	0.004	0.9	--
16	--	--	0.8	--
26	--	--	0.6	--
52	--	--	0.5	--

[1/] parts per trillion.

[2/] Calculated from table 1, assumes 2,4,5-T contains 0.1 ppm TCDD.

[3/] Assumes TCDD persistence as reported by Crosby and Wong (1977).

[4/] Assumes TCDD persistence as reported by Kearney et al. (1973).

[5/] Assumes TCDD persistence as reported by Miller et al. (1973).

BIOACCUMULATION OF TCDD

Only minute quantities of TCDD enter the forest environment as a result of the use of 2,4,5-T. The resulting concentrations of TCDD in the various forest compartments are not likely to result in the significant exposure of nontarget organisms. Bioaccumulation is a process which might concentrate TCDD in lower animals leading to significant exposure of higher tropic levels. Bioaccumulation is defined as the uptake or the accumulation of TCDD by an organism from its surrounding environment. As an example, fish exposed to 0.1 parts per trillion (ppt) TCDD in water may bioaccumulate TCDD to a concentration of 0.1 ppb in their flesh.

Low water solubility and relatively high fat solubility are physical properties of TCDD which suggest bioaccumulation might occur. This is confirmed in laboratory studies with aquatic organisms (Matsamura and Benezet 1973, and Isensee and Jones 1975). The magnitude of bioaccumulation varied from 1,000 to 60,000 times the concentration of TCDD in the water. These results indicate that bioaccumulation will occur in laboratory systems where a significant and continuing supply of TCDD is available.

During the mid 1960s, a portion of the Eglin Air Force Base (Florida) received massive applications of 2,4,5-T (and TCDD) during the development and testing of equipment and methods of application for defoliants to be used in Viet Nam. Test areas received 1,000 kg/ha 2,4,5-T. Analysis of a variety of samples from that area shows TCDD is present in significant quantities,and bioaccumulation has occurred (Young et al. 1976). These findings confirm the theoretical and the laboratory studies which indicate that when TCDD is present in significant quantities, bioaccumulation will occur. It is important to realize, however, that the magnitude of the application and the conditions which existed at the Eglin Air Force Base test center were extreme.

The bioaccumulation of TCDD has been investigated in three major studies in connection with the operational use of 2,4,5-T in the United States.

In 1973,the Environmental Protection Agency in cooperation with the Forest Service collected birds, fish, and mammals from several western forest areas recently treated with 2,4,5-T. These samples were analyzed for TCDD by EPA to obtain data for the 2,4,5-T hearing which had been scheduled for 1974. The analytical method was not adequate to establish the presence of TCDD, but could show which samples did not contain detectable levels of TCDD (low to middle part per trillion range). The results showed approximately 85% of the samples did not contain detectable levels of TCDD. How many of the remaining 15% actually contained TCDD is not known, but EPA described the results as only as "minutely suggestive" that they contained TCDD. Adequate confirmatory analyses have not been done.

Shadoff et al. (1977) used good analytical methods to look for TCDD accumulation in animals due to the use of 2,4,5-T in the Midwestern United States. They did not detect any TCDD (detection limit averaged less than 10 ppt) in samples of fish, water, mud, and human milk from areas in Arkansas and Texas with a long history of use of 2,4,5-T.

The EPA beef monitoring program initiated in 1974 is a cooperative effort involving several independent analytical laboratories able to detect TCDD conclusively in environmental samples. This is the most rigorous and substantive program of monitoring for TCDD in environmental samples. Samples (85 fat, 43 liver) from beef animals have been analyzed for TCDD (25% of these samples are from animals not grazed on areas sprayed with 2,4,5-T). EPA reports one beef fat sample contained TCDD at 60 ppt, two samples contain TCDD at 20 ppt, and five may have 5 to 10 ppt TCDD. EPA states "the analytical method is not valid below 10 ppt." Only one of the 43 liver samples contains TCDD, and the level is too close to the sample detection limits for quantitation. The EPA beef monitoring study shows bioaccumulation of TCDD in grazing animals is not sufficient to result in regularly detectable levels greater than 10 ppt in beef fat and liver.

The results of these various efforts indicate that if TCDD is present in the environment in a form which is available, then bioaccumulation will occur if organisms are exposed. The degree to which bioaccumulation of TCDD occurs in the field is dependent not only on the physical chemical properties of the compound, but also on its persistence and availability in the environment. Processes of degradation and dilution which operate in the natural environment reduce opportunities for organisms to be exposed to TCDD, thus reducing the degree to which bioaccumulation might occur. Monitoring indicates that substantial bioaccumulation (more than 10 ppt TCDD in the majority of the population) is not occurring in animals in or near areas treated with 2,4,5-T in current operational programs.

SUMMARY

The residues of 2,4,5-T and TCDD in specific parts of the forest are the result of the

behavior (movement, persistence, and fate) of these chemicals in the environment. These residue levels are estimates of the magnitude and duration of exposure organisms may receive from the operational use of 2,4,5-T. Completion of the assessment of toxic hazard requires consideration of the toxicological properties of both 2,4,5-T and TCDD with respect to these measures of organism exposure.

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