Bull. Environ. Contam. Toxicol. (1987) 38:369–376

Bulletin of Environmental Contamination and Toxicology

Degradation of Terbufos (Counter®) Soil Insecticide in Corn Fields Under Conservation Tillage Practices

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Conservation tillage is a system of managing crop residue on the soil surface by using minimum or no tillage (Unger and McCalla 1980). Reduced tillage leaves crop residue on the soil surface that can lessen the impact energy of raindrops and thereby signficantly reduce soil erosion. Surface translocation of agrochemicals may also be reduced (Baker et al. 1978; Baker and Johnson 1979). In contrast, conventional tillage (i.e., plowing) leaves the soil surface bare as crop residues are completely mixed into the soil. Plowed soil is easily loosened during intense rain storms and washed downslope. Farmers throughout the midwestern corn belt have adopted various conservation tillage systems to reduce soil erosion, protect water quality, conserve soil moisture, and reduce energy use.

Most pesticides used in the corn belt are applied directly to the soil in early spring. A knowledge of the physical, chemical, and biological behavior of pesticides in soil is critical to assessing efficacy against target pests and also in monitoring their translocation to nontarget areas. Characteristics of the soil environment, such as moisture, temperature, pH, organic matter content, and microbial populations, may differ between conservation tillage and conventional tillage systems (Siemens and Oschwald 1978; Blevins et al. 1983; Doran 1980; Lewis 1976; Unger and McCalla 1980). Although the soil parameters affected by tillage are those that have been shown to influence pesticide behavior, comparisons of pesticide behavior under different tillage practices are lacking.

Terbufos (Counter®) is a soil insecticide commonly used against corn rootworm larvae in the corn belt under both conventional and conservation tillage practices. This compound is extremely toxic (LD50 $<$ 10 mg/kg) and rapidly oxidizes in soil to two equally toxic metabolites: terbufos sulfoxide and terbufos sulfone (Laveglia and Dahm 1975, Chapman et al. 1982). Despite the millions of pounds of product used each year, only a few studies have characterized behavior and degradation of this compound in corn agroecosystems (Ahmad et al. 1979; Felsot et al. 1982;

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Stinner et al. 1986). Recently, Stinner et al. (1986) reported significantly faster dissipation of terbufos in untilled soil than in plowed soil.

One limitation to studying terbufos and its metabolites under field conditions has been the difficulty in analyzing the sulfoxide metabolite directly by gas chromatography. Using a bonded liquid phase for direct analysis of terbufos oxidative metabolites, we have investigated the degradation pattern of terbufos in two corn fields in Illinois that were managed by several different tillage systems.

MATERIALS AND METHODS

Degradation of terbufos (TS) and recovery of its primary environmental metabolites, terbufos sulfoxide (TSO) and sulfone (TSO_2), were evaluated under three tillage practices at a farm in Boone County, Illinois, in 1981 and 1982 and at the IL Northwestern Illinois Agricultural Research and Demonstration Center near Monmouth, Illinois (Warren County), in 1983. The tillage treatments consisted of adjacent plots managed either by spring plowing (Boone County) or fall plowing (Warren County) with a moldboard plow, chisel tillage, or no tillage. Insecticide treatments and untreated checks were replicated four times in a randomized block design within each tillage system.

In Boone County granular-formulated insecticide (Counter 15G) was applied after planting to single corn rows 20 m long at a rate of 1.12 kg/ha in an 18-cm band over the seed furrow by a bicycle-wheeled applicator. The insecticide was lightly incorporated into the soil in the chisel and plowed systems with either a rake or a drag chain. Insecticide was not incorporated in the no-till plots. In Warren County, Counter 15G was banded over the seed furrow during planting to replicate plots measuring 61 m long by 3 m wide (4 rows). The insecticide was applied through Noble metering units mounted on a John Deere 7000 series planter and incorporated with spring tines.

Immediately after application and at biweekly intervals for at least 2 months, soil cores (10 cm long x 5 cm diam.) were collected from each replicated plot. Three and 6 cores were collected from the middle of the insecticide bands at Boone County, and Warren County sites, respectively. The cores were composited for each replicate, and the soil was returned to the laboratory for sieving and analysis. Soil characteristics are shown in Table 1.

Soils were extracted by stirring 75-g subsamples with a mixture of hexane and acetone (Felsot et al. 1982). TS, TSO, and TSO_2 were quantitated directly by gas-liquid chromatography employing a Varian 1400 fitted with an alkalai flame ionization detector and an Ultrabond (Supelco, Inc.) column (61 cm x 2 mm i.d.). The oven temperature was programmed from 140°C to 200°C at a rate of 6°C/min. Flow rates for nitrogen carrier gas and hydrogen and oxygen flame-support gases were adjusted as needed to optimize peak resolution and sensitivity. TS, TSO, and TSO_2 eluted with relative retention times of 1.0, 3.3, and 3.7, respectively.

Table 1. Selected soil and field characteristics.[1/]

Tillage [2/]	Boone Co. MP	Boone Co. C	Boone Co. N	Warren Co. MP	Warren Co. C	Warren Co. N
Texture	----silt loam---			silt + silty clay loam		
pH	5.9	5.8	6.0	6.6	6.4	6.5
% organic carbon	1.1	1.3	1.2	2.6	2.7	2.7
% residue cover	-not determined-			5	41	83

[1/] Properties measured in the top 10-cm profile
[2/] MP = moldboard plow C = chisel till N = no-till

RESULTS AND DISCUSSION

Until recently, field studies on degradation of terbufos have been limited by lack of an analytical method for detecting TSO. Chapman et al. (1982) first reported the direct GLC analysis of TSO in soils from laboratory experiments using a 60-cm column of 1% OV-275 treated with phosphoric acid. We found that commercial preparations of bonded Carbowax 20 M, which is sold as Ultrabond, provided good resolution of TS and its metabolites using temperature programming. However, the sensitivity to TSO was almost ten times less than to TS and TSO_2. Nevertheless, the limit of quantitation for TSO was 20 ng/g soil in our experiments.

Recoveries of TS from soils immediately after application were below the theoretical concentration of 6 µg/g for an 18-cm banded application in almost all experiments (Figs. 1,2). However, we noted a significant recovery of TSO from soil collected immediately after application. Others have noted rapid oxidation of terbufos and other alkylthio-substituted phosphorodithioates, such as phorate, immediately after application (Laveglia and Dahm 1975; Lichtenstein et al. 1973). When total TS plus metabolites are considered, initial recoveries were close to theoretical application rates with two exceptions, the conventional till plot in 1982 (Fig. 1) and all plots in 1981. We believe that the low recovery in the 1982 moldboard plow treatment represents a sampling error. Samples from 1981 were stored frozen for almost a year and then refrigerated approximately one month before analysis. Breakdown of pesticide could not be ruled out because our laboratory studies indicate terbufos continues to dissipate under refrigeration. Samples in 1982 and 1983 were refrigerated

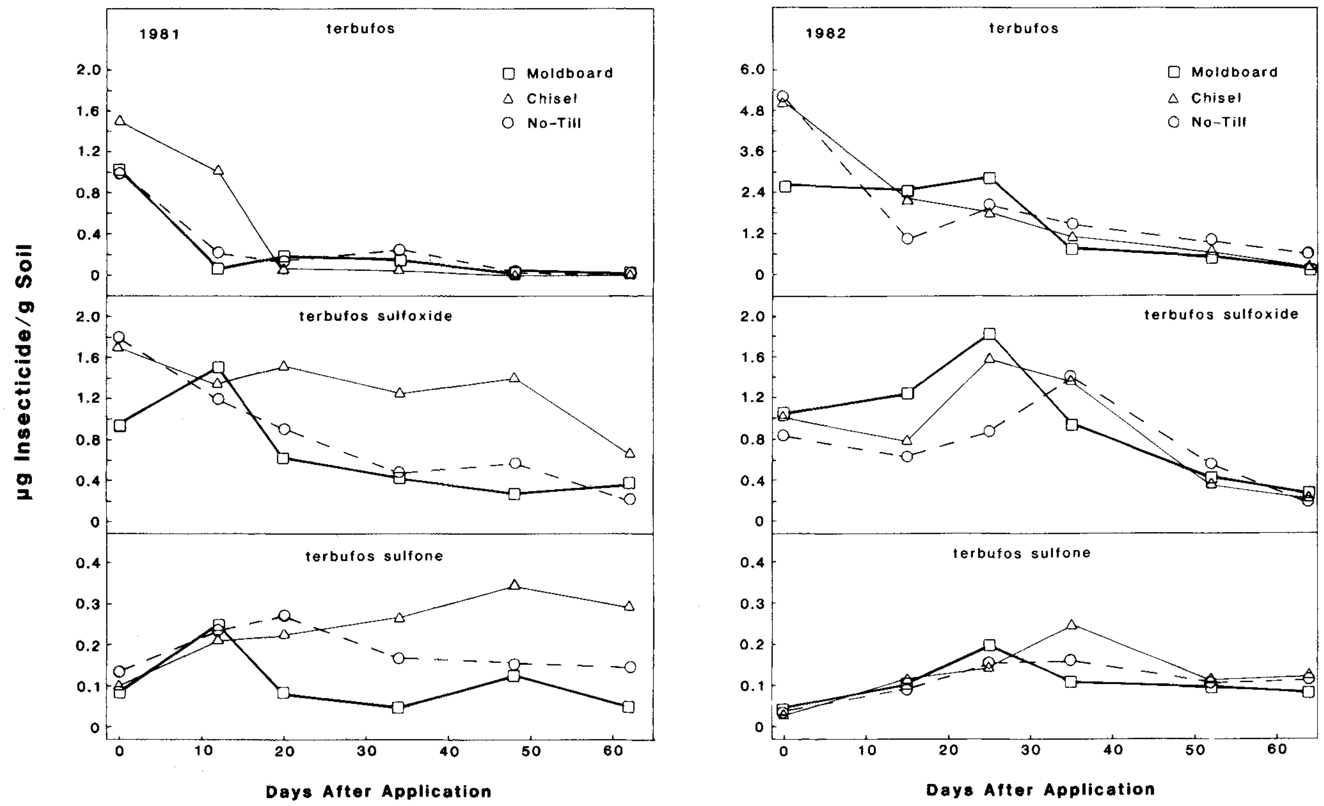

Figure 1. Degradation of terbufos and appearance of oxidative metabolites in soil managed by three different tillage systems in Boone County, Illinois, 1981 and 1982.

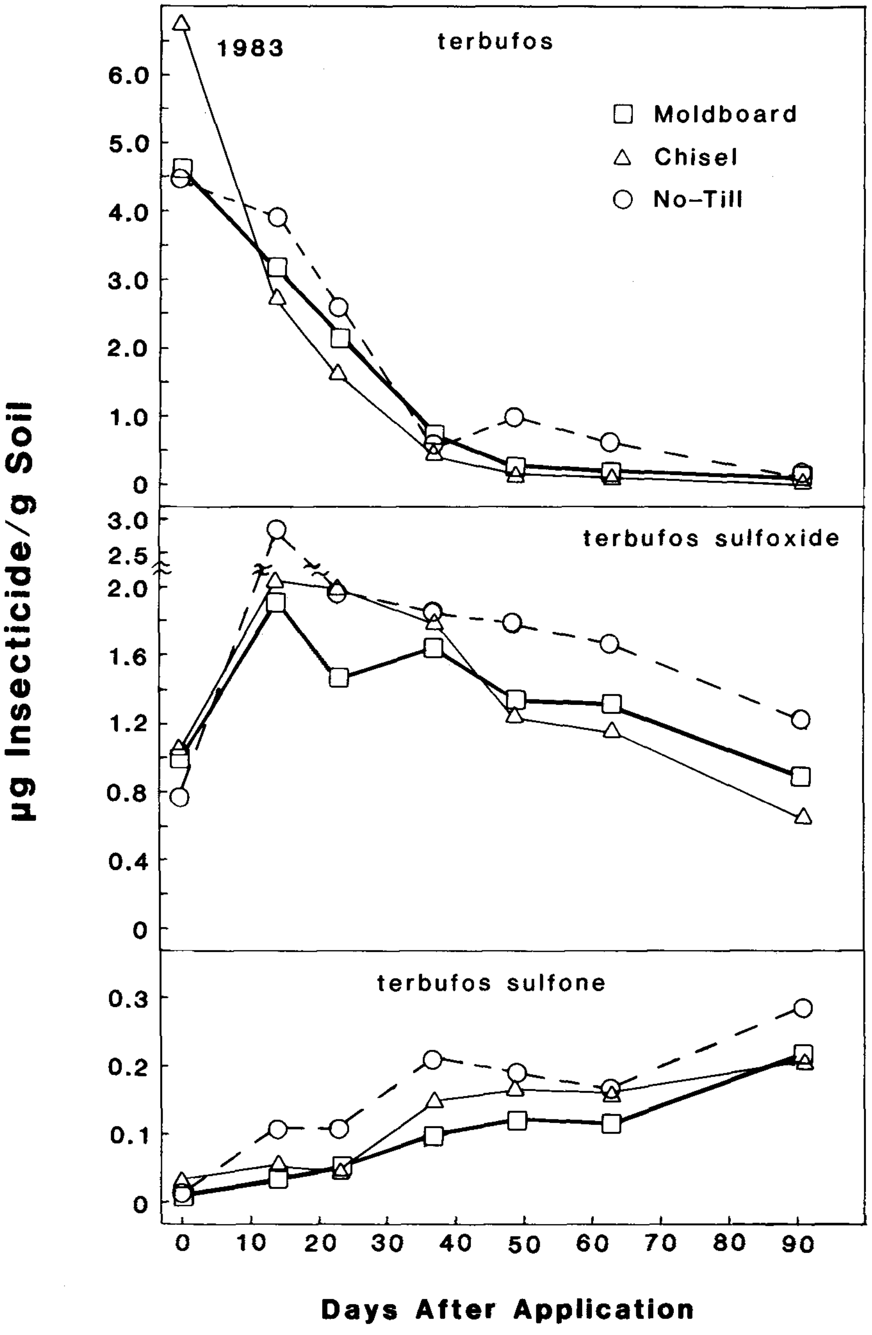

Figure 2. Degradation of terbufos and appearance of oxidative metabolites in soil managed by three different tillage systems in Warren County, Illinois, 1983.

for about a week prior to sieving, and then stored at -20°C until analyzed.

After 30 days TS degraded more slowly in all tillage treatments (Figs. 1, 2). Most of the TS was lost during the first month after application with corresponding increases in recoveries of TSO and TSO_2. This degradation pattern was most noticeable in the 1982 and 1983 experiments. TSO was the principle oxidative metabolite that formed rapidly from TS and was followed by a slower oxidation to TSO2. This pattern agreed with laboratory studies by Laveglia and Dahm (1975) and Chapman et al. (1982). Tillage treatments had no significant effect on rate of appearance of the metabolites, although higher concentrations of metabolites were recovered from chisel tillage in 1981.

In contrast to differences between plowed and no-till plots recently reported with respect to recovery of TS plus TSO_2 (Stinner et al. 1986), variabilities in TS recoveries during the first month of our studies generally precluded detection of significant differences among tillage systems. In fact, the dissipation rates of TS in plowed and no-till systems at Warren County were similar throughout the experiment (Fig. 3, Table 2). To further compare TS degradation among tillage treatments within each year, rate constants were calculated by assuming a first order dissipation mechanism (Table 2). Correlation coefficients ranged from 0.638 to 0.956, which indicated that first order analysis was not always the appropriate model for describing TS dissipation. Nevertheless, with the exception of no-till in 1982, the rate constants were similar. We concluded there were no major differences in dissipation of TS among tillage treatments. Similar trends were observed when first order analysis was applied to dissipation of total TS plus metabolites.

Table 2. First-order rate constants for dissipation of terbufos and total terbufos plus metabolites.

	Terbufos only			Total terbufos plus metabolites		
Tillage	1981	1982	1983	1981	1982	1983
Moldboard	0.077	0.052	0.050	0.037	0.040	0.018
Chisel	0.063	0.058	0.066	0.019	0.038	0.024
No-till	0.075	0.027	0.050	0.033	0.024	0.020

This study has focused only on the degradation of terbufos and appearance of toxic, oxidative metabolites for two to three months after application for two reasons. First, the fastest rates of degradation of many biodegradable organophosphate insecticides occur within one month after application. This period would be the most critical in determining the amount of pesticide available for surface washoff during heavy rains (Wauchope 1978). Second, corn rootworms, the intended insect targets of terbufos, most actively feed on roots during June. Thus, the pesticide needs to be present at a toxic concentration for as long as two months following an early spring application. Our results showed that the degradation of TS was not significantly affected by chisel tillage or no-tillage, and therefore, the amounts of insecticide available for either translocation or biological activity would not be different from conventional tillage.

Acknowledgements. Contribution of the Illinois Natural History Survey and the Illinois Agricultural Experiment Station, College of Agriculture, University of Illinois at Champaign-Urbana. Supported in part by Central Regional PIA Grant ILLU-12-0214, An Assessment of Corn Rootworm Soil Insecticide Behavior and Efficacy under Conservation Tillage Practices.

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Received July 21, 1986; accepted October 12, 1986.