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Seasonal Disappearance and Volatilization of Toxaphene and DDT from a Cotton Field[1]

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ABSTRACT

Volatilization and subsequent aerial transport is thought to be a major pathway of pesticide disappearance from application sites. Corroborative evidence obtained for agricultural pesticides under field conditions is scarce. The contribution of volatilization to the overall disappearance of toxaphene (chlorinated camphene) and DDT [1,1,1-trichloro-2,2-bis(*p*-chlorophenyl)ethane] from cotton (*Gossypium hirsutum* L.) was studied under field conditions in the "Delta" section of Mississippi. Drought conditions prevailed throughout most of the study. Measurements were made during two periods: (i) a 10.7-d period after toxaphene was applied by ground equipment to 50-cm-tall cotton plants, and (ii) a 32.7-d period after a similar application of a mixture of toxaphene and DDT to the same plants. Variable amounts of pesticide were unaccounted for (toxaphene, 17% first application, 54% second application; DDT, 72%) and were apparently lost during application and the following 3-h period before sampling of air, soil, and plants was begun. The calculated 50% disappearance times of toxaphene (4.7 d, first application; and 10.8 d second application) and DDT (10.3 d) on plants agreed reasonably well with previously reported values. Pesticide disappearance rates were linear functions of the pesticide loads on the plants. The volatile loss of toxaphene (as quantified by the last four chromatographic peaks) during the 10.7-d test period after the first application was 17% of the amount intercepted by the plants. The comparable volatile loss during the first 10.7 d after the second application (32.7-d test period) was 33% of the amount on the plants. Total toxaphene and DDT volatile losses during the complete 32.7-d test period were 53 and 58% of the amounts on the plants, respectively. Because of dry weather, no measurable pesticide volatilization occurred from soil. Disappearance rate changes, as well as volatilization rate changes, for toxaphene and DDT applied at the same time were approximately equal. The study provides additional evidence that post-application volatilization from plants is a major pathway of pesticide transport.

Additional Index Words: **chlorinated camphene, 1,1,1-trichloro-2,2-bis(*p*-chlorophenyl)ethane, *Gossypium hirsutum* L., flux density, momentum balance method, aerodynamic method, insecticide, pesticide disappearance.**

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Aerial transport is probably the principal method of pesticide dispersion over wide areas and into bodies of water far removed from their sites of manufacture, use, or disposal (2, 8, 19, 26, 31, 37, 42). The primary sources of pesticides in the air are drift and evaporation during application and post-application volatilization from plant and soil surfaces (10, 12, 23).

Despite previous interest in the volatilization and aerial transport of pesticides, too little is known about their volatile loss from plants and agricultural fields. Many factors are known to affect volatilization rates, but the quantitative effects of their interactions are difficult to predict. Potential volatility is related to the vapor pressure of the pesticide. However, the actual volatilization rate of surface-applied pesticides depends on environmental conditions that modify the vapor pressure of the pesticide at the solid-air or liquid-air interface (32) and the pesticide's diffusion rate from the evaporating surface. The volatilization rate increases

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Table 1—Dates and rates of pesticide application, and air sampling times.

Pesticide	Application		Air sampling				Length of sampling intervals†
			Beginning		End		
	Date	Rate	Date	Hour	Date	Hour	
		kg/ha					hour
Toxaphene I	16 Aug.	2.24	16 Aug.	1300	18 Aug.	1500	2
			19 Aug.	1200	21 Aug.	1200	2
			26 Aug.	0600	27 Aug.	0600	4
Toxaphene II‡	27 Aug.	3.73	27 Aug.	1000	29 Aug.	1400	2
DDT‡§	27 Aug.	1.30	27 Aug.	1000	29 Aug.	1400	2
			30 Aug.	0600	31 Aug.	0600	2
			9 Sept.	0600	10 Sept.	0600	4
			16 Sept.	0600	17 Sept.	0600	4
			28 Sept.	1000	29 Sept.	0200	4

† Air was continuously sampled during the indicated dates; sampling traps were replaced at the indicated intervals.
‡ Toxaphene II and DDT applied as a mixture.
§ DDT application was in accordance with EPA Experimental Use Permit no. 11312-EUP-6 issued 18 Aug. 1976.

with increasing wind speed, because air movement and turbulence decrease the thickness of the stagnant air layer immediately adjacent to the surface (16, 31). Vaporization from soil is controlled by pesticide solubility and adsorption, as well as by vapor pressure (7, 15, 18, 29, 31, 38, 41). For soil-incorporated pesticides, the rate of pesticide movement to the soil surface must be added to the factors controlling volatilization.

Studies concerned with the disappearance of DDT [1,1,1-trichloro-2,2-bis(*p*-chlorophenyl)ethane] and toxaphene (chlorinated camphene) from cotton (*Gossypium hirsutum* L.) plants have been reported (20, 25). In a greenhouse study, Nash and coworkers (20) measured the vapor loss of toxaphene and DDT from cotton plants in an enclosed glass chamber for 90 d. Volatile losses amounted to 24 and 15% of the applied toxaphene and DDT, respectively. In a field study where actual volatilization rates were not measured, Seiber et al. (25) concluded that vaporization was the major route of toxaphene loss from foliage. They presented evidence showing greatest loss of the chromatographically early eluting components of toxaphene. Only a few studies concerning pesticide volatilization rates from plants determined under field conditions have been reported (5, 22, 33, 34, 35, 40). Of these studies, only one (40) was concerned with toxaphene; about 25% of the toxaphene present in the canopy volatilized in 5 d.

This paper reports the seasonal disappearance and volatile loss of toxaphene[3] and DDT[4] from cotton under field conditions of the lower Mississippi River Valley. The relationships between the volatile losses and meterorological parameters are reported elsewhere (14).

MATERIALS AND METHODS

The study was conducted during August and September 1976 on a 24-ha portion of a 100-ha cotton field about 17 km northwest of Clarksdale, Miss. The field was uniformly level with no aerodynamic obstructions within the test area. The fetch/height ratio (distance from the edge of the field to the sampling site/uppermost air sampling height) was 170:1 in the direction of prevailing wind and was at least 100:1 in all other directions. The cotton height was 50 cm; the percent ground cover by the cotton, planted in rows 102 cm apart, was estimated to be about 45% (leaf area index [LAI] = 0.7). Because of drought conditions, neither canopy height nor percent ground cover increased during the study. Only 3.1 and 0.4 cm rain occurred in July and August, respectively; although 8.6 cm rain fell in September, it occurred too late to cause additional cotton growth.

Rates and dates of pesticide application (by ground equipment) are given in Table 1. All measurements necessary for calculation of pesticide flux density were begun after the upwind half of the test area had been sprayed. It took approximately 6 h to spray the entire test area. Flux density was determined periodically for the toxaphene-only treatment (hereafter called toxaphene I) during a 10.7-d period between 1300 hours on 16 August and 0600 27 August, and for toxaphene plus DDT treatment (called toxaphene II plus DDT) during a 32.7-d period between 1000 27 August and 0200 29 September. Toxaphene II plus DDT was applied as a mixture to the same site used for toxaphene I.

Theoretical Considerations

Necessary microclimatological measurements were made for calculating pesticide and water vapor flux densities by the energy and momentum balance (aerodynamic) methods (22). The specific methods are discussed by Harper et al. (14), who give a summary of assumptions and calculations. The flux densities reported here were calculated by the aerodynamic method; we discuss the theory, assumptions, and limitations of the method only briefly here. The vertical flux density of a pesticide is calculated as the product of a pesticide transfer coefficient, K_p, and the pesticide concentration gradient, $\Delta c/\Delta z$ (c = pesticide conc, and z = height above evaporating surface). The aerodynamic method assumes that vertical fluxes of momentum and pesticide are equal and that the momentum transfer coefficient, K_m, determined from wind speed profiles, can be substituted for the pesticide transfer coefficient. The aerodynamic method is valid only during adiabatic conditions. Thus, diabatic correction functions are necessary to adjust the flux calculations for conditions of thermal stability. Two such stability correction functions are the KEYPS (21) and Davis (24) methods. The vertical flux density, P, is given by:

$$P = K_m \Delta c/\Delta z,$$

where $K_m = k^2(u_2 - u_1)(z_2 - z_1)/\{\ln[(z_2 - z_d)/(z_1 - z_d)]\}^2\psi^2$. Here, c_1 and c_2 are pesticide concentrations, and u_1 and u_2 are wind speeds at heights z_1 and z_2, respectively; k is von Karman's constant (0.41); z_d is the crop displacement height; and ψ is the correction factor that depends upon the thermal stability of the atmosphere.

Microclimate and Environmental Data

Microclimate data recorded were profiles for wind speed, air and leaf temperatures, and air water-vapor content and incident radiation, net radiation, and wind direction (14). Wind speed was measured at six vertical heights with a rotating-cup anemometer system, along with corresponding air temperatures measured with aspirated five-junction thermopiles. Other parameters measured, which later added little to mathematical relationships between pesticide disappearance (and/or volatilization) and environmental factors, were soil temperature, soil heat flux, and soil water content. Analog signals from the various sensors were acquired by a data logger and stored on magnetic tape. Signals were collected at 60-s intervals and integrated over 2- and 4-h periods.

We determined leaf area by measuring the area of all leaves on randomly selected plants with an area meter; we used these measurements with planting density to determine the leaf area index (LAI).

Sampling and Chemical Procedures

AIR

Pesticide concentration gradients were measured in the center of the test area using an air-sampling system similar to that reported by Caro et al. (3). Air was sampled at each of three masts located at the corners of a centrally located equilateral triangle with 15-m sides. Samplers (250-mL gas washing bottles containing 100 mL hexane-washed

[3] This paper reports the results of research only. Mention of a pesticide does not constitute a recommendation for use by the USDA or its cooperators, nor does it imply registration under FIFRA as amended.
[4] DDT application was in accordance with EPA experimental use permit no. 11312-EUP-6 issued 18 Aug. 1976.

ethylene glycol) were positioned 70, 130, and 210 cm above the soil surface on each mast. On one of the masts, samplers were also positioned 20, 35, and 50 cm above the soil surface. Air was drawn through the samplers by vacuum pumps at 6 L/min. Air was sampled continuously during several 24- and 48-h periods after each pesticide application (Table 1). Samplers were changed at either 2- or 4-h intervals during each sampling period, and the ethylene glycol was quantitatively transferred from the sampler with 25 mL H_2O to a 300-mL amber bottle. Approximately 100 mL hexane was then added to the bottle, which was capped with a Teflon-lined lid and refrigerated at 4°C until extraction.

The contents of each amber storage bottle were mixed for 1 h with a magnetic stirrer, quantitatively transferred to a 500-mL separatory funnel, and the ethylene glycol/water fraction drained. The hexane was washed once with H_2O, dried with anhydrous Na_2SO_4, and adjusted to a volume appropriate for gas chromatographic analysis. Efficiencies for trapping and extraction were 90 and 92%, respectively. The lower limits of detection for DDT and toxaphene in air were about 1 and 15 ng/m³, respectively.

PLANTS

About 3 h after pesticide application, and at the beginning of each of the other 24- and 48-h sampling periods, 20 cotton plants were collected for determination of the pesticide load on plants. All leaves, petioles, and bolls were stripped from each plant and placed in 1-L jars. The jars were filled with hexane and stored at 4°C for a minimum of 1 week.

Hexane from the jars containing the plant material was decanted into a separatory funnel. The plant material was then washed with fresh hexane, which was also added to the separatory funnel. Accumulated water was drained and the hexane was dried with anhydrous Na_2SO_4. A 50-mL aliquot of the hexane was added to a 2- by 10-cm prewashed (hexane) Florisil column. The insecticides were eluted with 200 mL of 85:15 (v/v) hexane/ethyl ether. The eluate volume was then adjusted for gas chromatographic analysis. The plant extraction procedure resulted in 95% recovery.

SOIL

Soil in the test area was sampled before and after each spray application, and at the beginning of each 24- and 48-h sampling period. Metallic rings, 7.6 cm i.d. by 2.5 cm deep, were driven into the soil (randomly in rows and middles) until the ring-tops were flush with the soil surface. The soil in the ring was excavated and placed in a 4-L bucket. The test area was divided into six units, roughly equal in size. Five separate 20-ring-composite-samples were collected from each unit. The soils were air-dried and frozen until extraction.

Ten-gram samples were Soxhlet-extracted with 200 mL of an azeotropic (41:59 v/v) hexane/acetone mixture. The extract was partitioned in a separatory funnel, washed with H_2O to remove acetone, dried with anhydrous Na_2SO_4, and diluted or concentrated to an appropriate volume for gas chromatographic analysis. The procedure resulted in >95% recovery.

Gas Chromatographic Analyses

Aliquots (5 μL/injection) of the hexane extracts of air and soil samples were analyzed for DDT and toxaphene using a Micro-Tek model MT-220[3] gas chromatograph. A Tracor model 222 gas chromatograph was used to analyze leaf extracts. Both gas chromatographs were equipped with ^{63}Ni high-temperature electron-capture detectors operated at 295°C. Inlets and column ovens were operated at 220 and 215°C, respectively. The carrier gas (filter-dried N_2) flow rate was 150 cm³/min. The columns were Pyrex glass tubes 180 cm long by 6 mm o.d. by 4 mm i.d., packed with 5% OV-1 on 80–100 mesh Chromosorb W (high-performance, AW, DMCS). The DDT in hexane extracts was quantified by comparing peak heights with those produced by standard solutions. Toxaphene was quantified by triangulating the last four peaks of the chromatogram, and comparing the areas with those obtained from standard solutions. Gaul (9) reported that quantification of the last four chromatographic peaks compared favorably with values obtained using the entire toxaphene chromatogram. The conclusion was based on data derived from apparently unweathered samples. Seiber et al. (25) presented evidence that the components of the early eluting chromatographic peaks of toxaphene disappeared (volatilized?) from cotton plants at a faster rate than the components of the slower eluting peaks. Presumably, the components of the early eluting peaks have a higher vapor pressure than those of the later eluting peaks. We used Gaul's technique as an expedient to eliminate the need for time-consuming cleanup steps for the numerous (ca. 1,750) air and soil samples. Use of this technique on air samples from weathered sites may have resulted in an underestimation of the total volatile loss of toxaphene from plants, and in an overestimation of the total toxaphene load on plants and soil.

[3]Mention of a trademark or proprietary product is for the convenience of the reader and does not imply any endorsement by the USDA over similar products that may also be suitable.

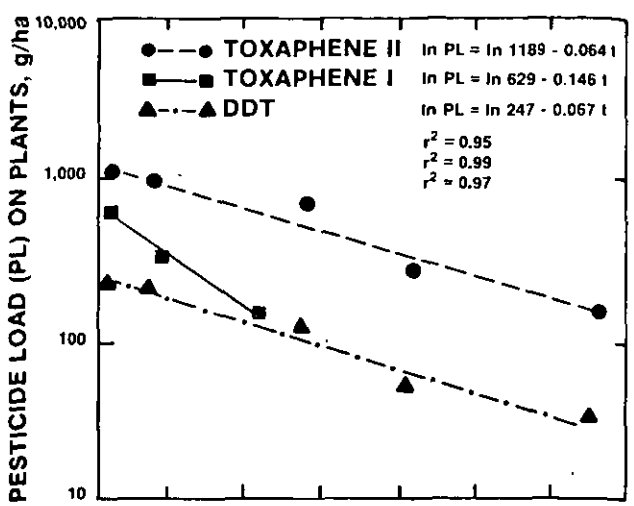

Fig. 1—Pesticide load on cotton plants as a function of time after application.

RESULTS AND DISCUSSION

Measurements of pesticide concentration gradients in the 0- to 50-cm zone above the soil surface revealed no measurable volatilization from the soil surface. The abnormally dry condition of the soil was a factor in attenuating pesticide flux density from the soil (11, 15, 29, 30). Pesticide soil concentrations during the study are presented in greater detail by Harper et al. (14).

The pesticide load on cotton plants as a function of time after application is presented in Fig. 1. The equations in Fig. 1 were used to calculate the amounts of pesticide intercepted by the plants and the amounts that disappeared from the plants during the test periods (Table 2). The amounts of toxaphene I, toxaphene II, and DDT intercepted by the plants were 28, 28, and 19% of the amounts applied, respectively. The total toxaphene load on the plants after the toxaphene II application was 1,189 g/ha (132 g/ha residual toxaphene I + 1,057 g/ha toxaphene II). In other studies, measured toxaphene loadings on plants 1 to 2 h after application were low and somewhat variable, ranging from 9% to 48 ± 26% (39, 40).

The amounts of applied toxaphene I, toxaphene II, and DDT intercepted by soil were 55, 18, and 9%, respectively (Table 2). The reasons for the large differences in the percentages intercepted by soil are unknown. The plant canopy and percent ground cover

Table 2—Pesticides intercepted by plants and soil, and lost from plants.

Pesticide	Amount of pesticide			Pesticide disappearance§ from plants during—		Volatilization loss¶ from plants during—	
		Intercepted					
	Applied†	Soil	Plants‡	10.7	32.7	10.7	32.7
	g/ha						
Toxaphene I	2,240 ± 75	1,227 ± 26	629 ± 262	497 ± 57	–	106 ± 17	–
Toxaphene II	3,730 ± 201	653 ± 44	1,057 ± 475	590 ± 83	1,042 ± 105	394 ± 82	629 ± 115
DDT	1,300 ± 64	121 ± 8	247 ± 75	126 ± 15	219 ± 17	90 ± 20	143 ± 25

† Error (1 SD) propagated for spray volume and pesticide spray concentration.
‡ Error (1 SD) propagated for plant population and pesticide mass on plants.
§ Disappearance calculated from equations in Fig. 1. Errors determined from plant samples collected at beginning and end of individual experiments.
¶ Volatilization loss calculated by integration of area under loss rate curves. Errors determined from standard deviations of pesticide flux through two sampling planes, i.e., 20-80 and 80-160 cm above canopy surface.

remained unchanged; the same sprayer was used. Climatic conditions were similar during both applications (e.g., toxaphene I application vs. toxaphene II + DDT application/mean air temperature, 34 vs. 30°C; mean wind speed, 159 vs. 172 cm/s; relative humidity, 49 vs. 65%). Nevertheless, the data show that only 17% of the toxaphene I application remained unaccounted for, whereas 54 and 72% of the toxaphene II and DDT, respectively, were apparently lost through evaporation and drift during application. Since the reported vapor pressure of DDT is only slightly lower than that for toxaphene (36), the tendency for vaporization and subsequent drift losses of the vapor during the application should not be any greater for DDT than toxaphene.

The slopes of the curves in Fig. 1 indicate that loss of toxaphene I from the plants was faster than for either toxaphene II or DDT. Disappearance of toxaphene II and DDT occurred at about the same rate. About 79% of the toxaphene I load on the plants disappeared during the 10.7-d test period (mean air temperature 27°C), while about 50 and 51% of the toxaphene II and DDT, respectively, disappeared during the first 10.7 d of their test period (mean air temperature 24.5°C). About 88 and 89% of the toxaphene II and DDT, respectively, disappeared during 32.7 d (mean air temperature 23°C). In earlier reports, toxaphene disappearance from cotton plants was 40% in 5 d in Mississippi (40) (mean air temperature 25°C, mean wind speed 259 cm/s) and 59% in 28 d in California (25) (no meteorological data reported). For comparison, about 52 and 27% of the toxaphene I (mean air temperature 26.4°C, mean wind speed 134 cm/s) and toxaphene II (mean air temperature 26.1°C, mean wind speed 120 cm/s), respectively disappeared in 5 d, and 83% of the toxaphene II disappeared in 28 d.

Equations giving the calculated pesticide disappearance from plants as linear functions of calculated pesticide loads on plants are given in Table 3. All calculations were based on the equations in Fig. 1. Even though the toxaphene I load was intermediate between the toxaphene II and DDT loads, toxaphene I disappeared fastest. The daily disappearance rate for toxaphene I was about 17% of the plant load, compared with about 6% for both toxaphene II and DDT. Toxaphene II and DDT disappeared at the same rate, in terms of percent plant load, even though the toxaphene II plant load was four times greater than the DDT plant load.

The calculated 50% disappearance times (DT_{50}) of toxaphene I, toxaphene II, and DDT on plants were 4.7, 10.8, and 10.3 d, respectively. These values are only approximate, because of the lack of replication and the relatively short time intervals over which they were measured. Nevertheless, the values fall well within ranges reported earlier (43). The shorter DT_{50} for toxaphene I compared with toxaphene II is probably due to the greater mean temperature, the greater change in volatilization rate, and the shorter time interval of measurement during the toxaphene I test period. The disappearance of many pesticides in the environment does not always follow first-order kinetics (13). Their disappearance curves may be thought of as being constructed from two or more linear segments, each succeeding segment having a flatter slope than the preceding one. Thus, if the DT_{50} is measured over a short time interval just after application, a smaller value may be calculated than if the measurement time were longer, e.g., 4 or 5 DT_{50}.

Nash et al. (20) reported half-lives of 19.3 and 29 d for toxaphene and DDT, respectively, from cotton plants grown in glass agroecosystem chambers in a greenhouse. Air velocity in the glass chambers (about 10 cm/s) was an order of magnitude lower than those typically measured in the field in our study. Volatile losses would be reduced at the lower air velocities. Additionally, greenhouse and chamber glass would effectively filter most ultraviolet radiation and reduce disappearance due to photodegradation. Both factors would result in longer half-lives. Half-lives of pesticides on plant surfaces are lumped-parameter values that are the integrated results of several processes (volatilization, degradation, washoff by rain, and absorption and metabolism by plants). Thus, field measurements of half-lives, or DT_{50} depend on many variables and are site-specific.

Flux densities for toxaphene I, toxaphene II, and DDT are shown as functions of time in Fig. 2. Since

Table 3—Equations relating pesticide disappearance, pesticide flux density, and pesticide load on plants.

Pesticide	Equation†
Toxaphene I	$D = 0.04 + 0.17\ PL$
Toxaphene II	$D = -0.03 + 0.06\ PL$
DDT	$D = -0.07 + 0.06\ PL$
Toxaphene I	$P = -2.17 + 0.03\ PL$
Toxaphene II	$P = -4.99 + 0.05\ PL$
DDT	$P = 1.31 + 0.04\ PL$

† Equations derived from relationships given in Fig. 1 and 2. D = disappearance, g ha^{-1} d^{-1}; PL = plant load, g ha^{-1}; and P = flux density, g ha^{-1} d^{-1}.

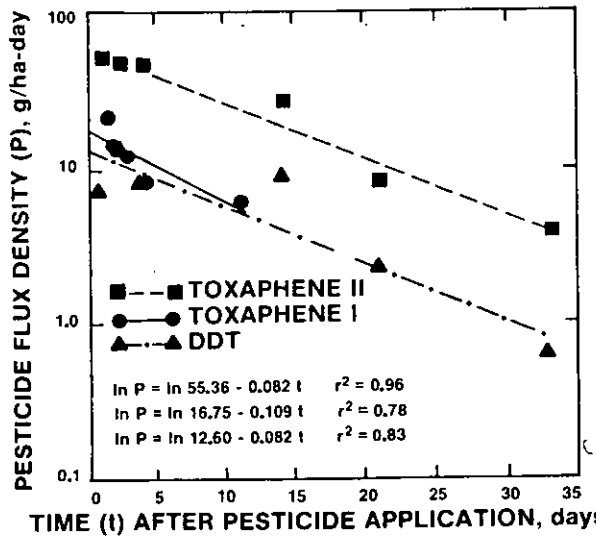

Fig. 2—Pesticide flux density as a function of time after application.

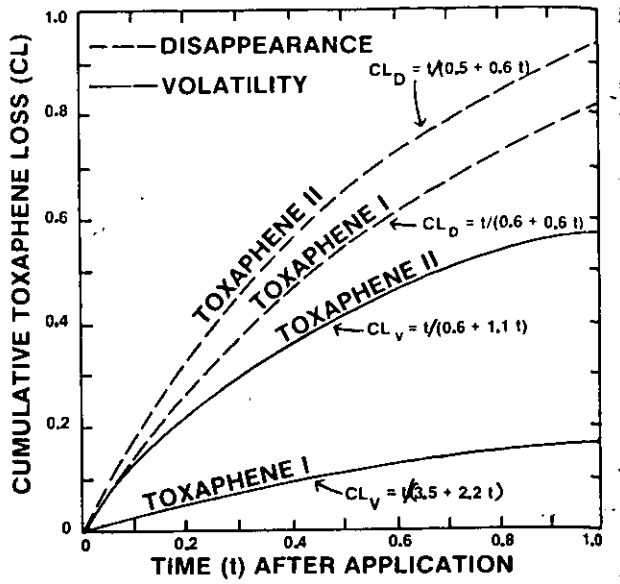

Fig. 3—Scaled (fraction of initial plant load) cumulative losses of toxaphene I and II as functions of scaled time.

pesticide concentration gradients were measured across two horizontal planes (the 70- to 130-, and 130- to 210-cm zones), two estimates of flux density were calculated for each sampling period. Thus, each data point in Fig. 2 is the mean of two measurements. As expected, because of the greater plant load, the volatilization rate (g/ha-d) was much greater for toxaphene II than for toxaphene I or DDT. However, the volatility rate change of toxaphene I decreased more rapidly than that of toxaphene II or DDT. The volatility rate change for the latter pair decreased at about the same rate.

The equations in Fig. 2 were used to calculate the volatile losses given in Table 2. The calculated volatile losses for toxaphene I, toxaphene II (10.7 d), toxaphene II (32.7 d), and DDT were 17, 33, 53, and 58% of the plant loads, respectively. These volatile losses correspond to 21, 67, 60, and 65% of the measured decrease in plant loadings during the same periods. In an earlier study (40), about 25% of the toxaphene load on cotton plants volatilized in 5 d. About 10, 19, and 21%, respectively, of the toxaphene I, toxaphene II, and DDT volatilized in 5 d. The relationship between flux density and pesticide load on plants shows the daily flux density was about 3, 5, and 4%, respectively, of the toxaphene I, toxaphene II, and DDT load on the plants (Table 3).

The scaled (fraction of initial plant load) cumulative losses of toxaphene I and II as functions of scaled time are shown in Fig. 3. The cumulative disappearance (CL_D) curves for toxaphene I and II are similar, i.e., their slopes are identical and the difference in intercepts probably results from the difference in initial plant loads. The curves for cumulative volatile loss (CL_V) show that volatilization contributed much more to the total disappearance of toxaphene II than toxaphene I.

Toxaphene vapor pressure has been reported as 0.17–0.40 mm Hg (absolute) at 25°C (17), 0.2–0.4 mm Hg (absolute) at 20°C (27), and 1×10^{-6} mm Hg at 20–25°C (6, 36). The values reported as "absolute" were presumably determined in vacuo, whereas the other measurements were at atmospheric pressure. Since toxaphene is composed of a mixture of more than 170 components (4) having a wide range of gas chromatographic retention times, no single vapor pressure value can represent all the components. Undoubtedly, the components of the slower eluting chromatographic peaks have much lower vapor pressures than the components of the early eluting peaks. In our study, the percentage loss of toxaphene II (only the last four chromatographic peaks were quantified) was very similar to that for DDT. The similarities in percentage loss suggests that the components of the last four chromatographic peaks of toxaphene have vapor pressures similar to that reported for DDT [1.5×10^{-7} mm Hg at 20°C (1, 28)].

In summary, this study provides evidence that post-application volatilization can be a major pathway of pesticide loss from application sites for some pesticides. About 80% of the initial toxaphene I load on the plants disappeared in 10.7 d, while about 90% of the initial toxaphene II and DDT loads on the plants disappeared in 32.7 d. Measured 50% disappearance times were 4.7, 10.8, and 10.3 d, respectively, for toxaphene I, toxaphene II, and DDT. Volatile losses accounted for 21, 60, and 65% of the disappearance of toxaphene I, toxaphene II, and DDT, respectively. Pesticide disappearance rates and volatilization rates decreased exponentially with time, and were linearly related to the pesticide load on the cotton plants. Disappearance rates and volatilization rates (in terms of percent of the pesticide load on plants) were about equal for toxaphene and DDT applied at the same time. Similarities in percent loss suggest that the components of the last four chromatographic peaks of toxaphene have vapor pressures similar to DDT.

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