

Pesticide Concentrations and Yields in Runoff from Silty Soils in the Lower Mississippi Valley

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Toxaphene (chlorinated camphene), DDT [1,1,1-trichloro-2,2-bis(*p*-chlorophenyl)ethane], DDE [1,1-dichloro-2,2-bis(*p*-chlorophenyl)ethylene], trifluralin (α,α,α -trifluoro-2,6-dinitro-*N,N*-dipropyl-*p*-toluidine), and sediment concentrations in runoff from an 18.7-ha watershed, planted to continuous cotton (*Gossypium hirsutum* L.), were measured from 1973 through 1978 to determine pesticide and sediment yields. Storm pesticide yields for DDT, DDE, trifluralin, and toxaphene (in years when not applied) were linear functions of storm sediment yields. During years when toxaphene was applied to the watershed, storm toxaphene yields could be correlated with storm sediment yields only if the data were separated into periods that were similar with respect to tillage and toxaphene-application regimes. In general, DDT (not applied after 1972) and DDE concentrations during 1973-1978 and toxaphene concentration in 1973 and 1978 (years of no toxaphene application) were linear functions of sediment OM concentration and of OM plus clay concentration but were nonlinear functions of sediment concentration.

Modern agriculture relies heavily on pesticides because of their effectiveness in controlling insect vectors of diseases and in reducing crop losses. Unfortunately, pesticides have the potential to pollute the environment because of continuous chemical exchange between soils, water, air, and living organisms. Although pesticide transport in runoff has been recognized as a problem for some time, the magnitude of loss and frequency distributions of pesticide concentrations and yields in runoff from agricultural lands have only recently begun to be accurately characterized. Such information is needed to develop best-management practices for nonpoint pollution control and to develop and verify models for predicting pesticide transport.

An earlier report (McDowell et al., 1981) discussed relationships between water discharge, sediment yield, and toxaphene (chlorinated camphene) yield, toxaphene persistence in soil, and mode of transport and concentration frequency distributions for toxaphene in runoff from a lower Mississippi Valley watershed (Figure 1, watershed 802) with silty clay topsoil (1% sand, 52% silt, and 47% clay). The current report discusses similar data for toxaphene, DDT [1,1,1-trichloro-2,2-bis(*p*-chlorophenyl)ethane], DDE [1,1-dichloro-2,2-bis(*p*-chlorophenyl)ethylene], and trifluralin (α,α,α -trifluoro-2,6-dinitro-*N,N*-dipropyl-*p*-toluidine) in runoff from an adjacent watershed (Figure 1, watershed 803) with lighter-textured topsoil (9% sand, 59% silt, and 32% clay).

MATERIALS AND METHODS

An 18.7-ha watershed (watershed 803) on the G. L. McWilliams' farm near Clarksdale, MS, was used for the study. The watershed had been in continuous cotton for a number of years and had received a wide assortment of pesticides. The watershed contained several soils (Table

Table I. Description of Watershed Soils

soil	% of watershed	classification
Bruin silt loam	57	coarse, silty, mixed, thermic Fluvaquentic Eutrochrepts
Commerce silt loam	15	fine silty, mixed, nonacid, thermic Aeric Fluvaquents
Tunica silty clay	11	clayey over loamy, montmorillonitic, nonacid, thermic Vertic Haplaquepts
Sharkey silty clay	17	very fine, montmorillonitic, nonacid, thermic Vertic Haplaquepts

I) and had been land formed for drainage with mean slopes of 0.2%. Watershed runoff was directed by shallow V ditches into a 1.6-ha pond located in the watershed. Most of the runoff was measured at Station 803 (Figure 1); however, 36% of the runoff entered the pond through an ungaged structure. All net runoff from watersheds 802 and 803 was measured at the pond outlet (Station 804). Instruments to measure surface runoff and sample the flow for sediment and chemical concentrations (Murphree et al., 1976; Parr et al., 1974) were installed at Station 803. Collection of water discharge and sediment yield data began in July 1972 and collection of pesticide yield data in March 1973.

The watershed was planted to cotton each year of the study, and cultural practices typical of those normally used for cotton in the Mississippi Delta were followed, i.e., shredding cotton stalks after harvest, disking and forming rows in the late winter or early spring, applying preplant herbicides and fertilizers in the spring, and planting, cultivating, and applying pesticides during the growing season. Pesticide application dates and rates for 1972-1979 are given in Table II.

Runoff samples (800 mL) were collected with a PS-69 automatic pumping sampler at 10-min intervals throughout each runoff event (storm) and were refrigerated at 4 °C. A discharge-weighted composite sample representing each storm was prepared from aliquots of the instantaneous samples. The volume of each aliquot was proportioned to the volume of water passing through the flume during each 10-min period. Thus, all mass/unit volume concentrations reported herein are discharge weighted.

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Table II. Pesticides Applied to Watershed, 1972-1979

year	month	application		total applied, kg ha ⁻¹		
		rate, kg ha ⁻¹	no.	trifluralin	toxaphene	DDT
1972	March	1.12	1	1.12		
	May ^a	2.24	2		4.48	
	July-September	2.24	7		15.68	
	July-September	1.12	7			7.84
1973	May	1.12	1	1.12		
1974	April	1.12	1	1.12		
	August-September	1.68	6		10.08	
1975	April	1.12	1	1.12		
	May	2.24	1		2.24	
	August-September	1.68	4		6.72	
	September	2.24	1		2.24	
1976	April	1.12	1	1.12		
	August	2.24	1		2.24	
	August	3.73	1		3.73	
1977	April	1.12	1	1.12		
	July-August	2.46	5		12.30	
1978	April	1.12	1	1.12		
1979	none (watershed planted to soybeans)					

^a May applications of toxaphene were for control of cutworms; July-September applications were for control of cotton bollworms [*Heliothis zea* (Boddie)] and tobacco budworms [*Heliothis virescens* (Fabricius)].

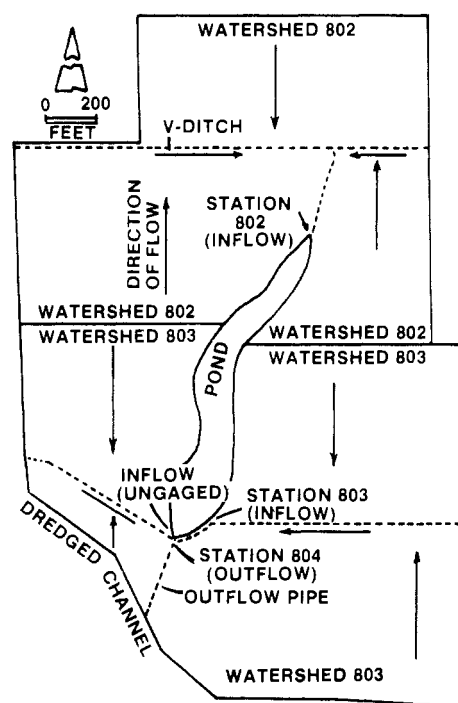


Figure 1. Watershed map.

Discharge-weighted mean concentrations of pesticide, sediments, and sediment-associated organic matter (OM) for individual runoff events are referred to in this report as storm pesticide, storm sediment, and storm sediment OM concentrations, respectively.

Total solids (dissolved plus suspended) in runoff were determined by drying a 100-g aliquot of the sample overnight at 105 °C and weighing. Another aliquot of the same runoff sample was filtered through a 0.45- μ m Millipore filter to separate the dissolved and suspended solids. The difference between total and dissolved solids equaled sediment concentration in milligrams per liter.

Organic matter in soil and sediment was determined by digestion with 30% H₂O₂ (Jackson, 1958). The particle-size distribution of soils and sediments (dispersed in sodium hexametaphosphate) was determined by the sieve-pipet method (Guy, 1969).

The pesticides were extracted by sonifying 100 mL of runoff suspension (water and sediment were not separated)

and an equal volume of a 1:1 hexane-acetone mixture for 1.5 min. The hexane layer was removed, dried with Na₂SO₄, and adjusted volumetrically for gas chromatographic analysis.

The watershed soil was sampled to a 15-cm depth each spring in 1973-1978 to determine residual pesticide concentrations. For sampling purposes the watershed was divided into six areas (ranging in size from 1.5 to 4.0 ha), and five samples were collected from each area. Each sample was a composite of forty 2-cm diameter soil cores taken randomly from within the area. After collection, soil samples were air-dried and frozen until extraction. Ten-gram subsamples were Soxhlet extracted with 200 mL of an azeotropic (41:59 v/v) hexane-acetone mixture. The extract was placed in a separatory funnel and watered out with H₂O to force the compounds into the hexane phase; the hexane layer was then dried with Na₂SO₄ and adjusted to an appropriate volume for gas chromatographic analysis. The pesticide concentrations for the five samples in each area were averaged, and the average values for the six areas were used to calculate (area-weighted basis) the concentrations for the watershed as a whole.

Aliquots (5 μ L/injection) of the hexane extracts were analyzed for pesticides by using a Micro-Tek Model MT-220 gas chromatograph equipped with a ⁶³Ni high-temperature electron-capture detector operated at 280 °C. The inlet oven and column oven were operated at 225 and 200 °C, respectively (column oven was 140 °C for trifluralin). The carrier gas (filter-dried N₂) flow rate was 200 cm³ min⁻¹. The columns were Pyrex glass tubes (180 cm long \times 6 mm o.d. \times 4 mm i.d.) packed with 5% OV-1 on 80-100-mesh Chromosorb W (high performance, AW, DMCS). Trifluralin was quantified by comparing peak heights to those produced by standard solutions. DDT, DDE, and toxaphene (last four chromatographic peaks) were quantified by comparing peak areas to those obtained from standard solutions. The extraction and analysis techniques resulted in \geq 90% and \geq 95% recovery for fortified runoff and soil samples, respectively.

RESULTS AND DISCUSSION

Each of the water years began on March 1 and ended on Feb 28 of the following calendar year, e.g., March 1, 1973, through Feb 28, 1974, March 1, 1974, through Feb 28, 1975, etc. For brevity, the water years will be referred to as 1973, 1974, etc.

Table III. Pesticide Concentrations in Watershed Soil

sampling date	concentration, $\mu\text{g g}^{-1}$			
	toxaphene	DDT	DDE	trifluralin
1973 (March)	1.58 ± 0.02	1.29 ± 0.02	0.26 ± 0.01	0.020 ± 0.001
1974 (May)	1.46 ± 0.05	ND ^a	ND	ND
1975 (June)	4.15 ± 0.14	0.94 ± 0.01	0.35 ± 0.01	0.056 ± 0.002
1976 (March)	2.78 ± 0.11	0.67 ± 0.02	0.089 ± 0.002	0.013 ± 0.001
1977 (March)	6.08 ± 0.26	0.94 ± 0.04	ND	ND
1978 (March)	4.91 ± 0.14	0.52 ± 0.00	ND	ND

^a Not determined.

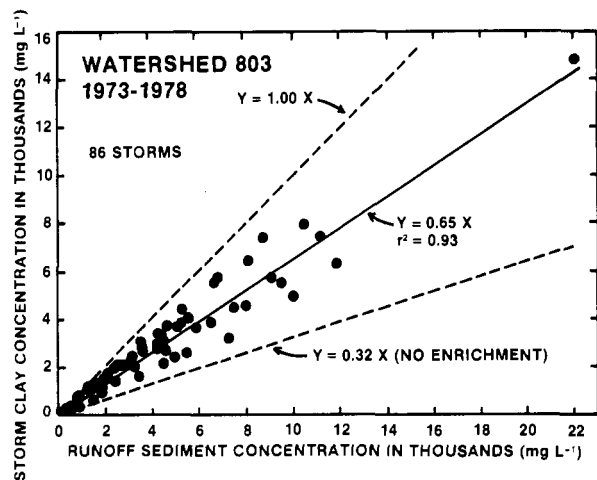


Figure 2. Storm clay concentration as a function of sediment concentration in runoff, 1973–1978.

Pesticide Residues in Soil. The pesticide concentrations in the watershed soil (0–15-cm depth) are given in Table III. For toxaphene and trifluralin, the amount applied during the spring–summer spray season was not related to the amount recovered from the soil the following spring. For example, 20.2 and 6.0 kg ha^{-1} toxaphene was applied in 1972 and 1976, respectively, but the corresponding amounts recovered from soil the following spring were 1.58 and 6.16 $\mu\text{g g}^{-1}$. Doubtless, a number of variables would affect the influence of the annual pesticide loading rate on residual soil concentration.

Since DDT was not applied to the watershed after 1972, the decrease in residual soil DDT concentration should represent its natural disappearance rate under the climatic conditions observed. We calculated that the 50%-disappearance time (DT_{50}) was 4.5 years. This value is greater than the half-life values of DDT reported by Edwards (1973) for a variety of soils (2.8 years), Tarrant et al. (1972) for Oregon forest soils (3 years), and Ware et al. (1978) for nonirrigated Arizona desert soils (2.5 years) but is less than those reported by Nash and Woolson (1967) for Maryland test-plot soils (10.5 years) and Owen et al. (1977) for Maine forest soils (35 years).

Sediment and Pesticides Concentrations in Runoff.

Sediments. The clay concentration in individual storm runoff, measured in dispersed samples, was a linear function of sediment concentration over a wide range of flow conditions in 1973–1978 (Figure 2). The mean clay content of the sediments was 65% as compared with the 32% clay content of the watershed soil, and indicates a clay enrichment factor (selectivity in erosion, transport, and/or depositional processes) of 2.0. Unlike clay concentrations, storm sediment OM concentration in runoff was nonlinearly related to sediment concentration in 1973–1978 (Figure 3). The nonlinearity probably resulted from OM enrichment at low sediment concentrations (Figure 4). Since OM is concentrated in the soil surface and has low

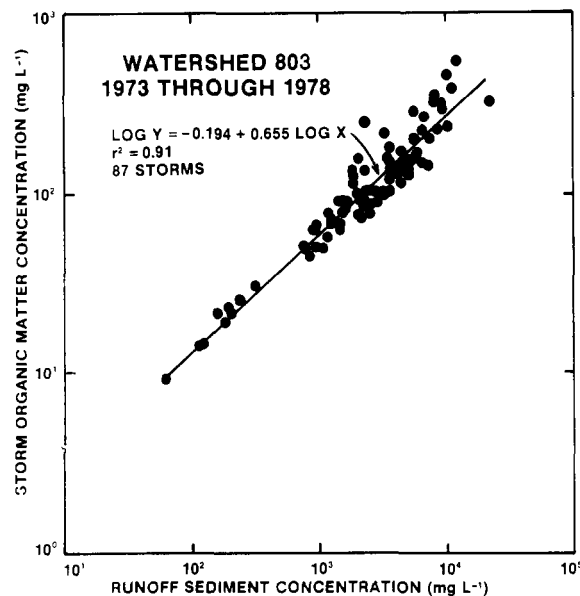


Figure 3. Storm sediment organic matter concentration as a function of sediment concentration in runoff, 1973–1978.

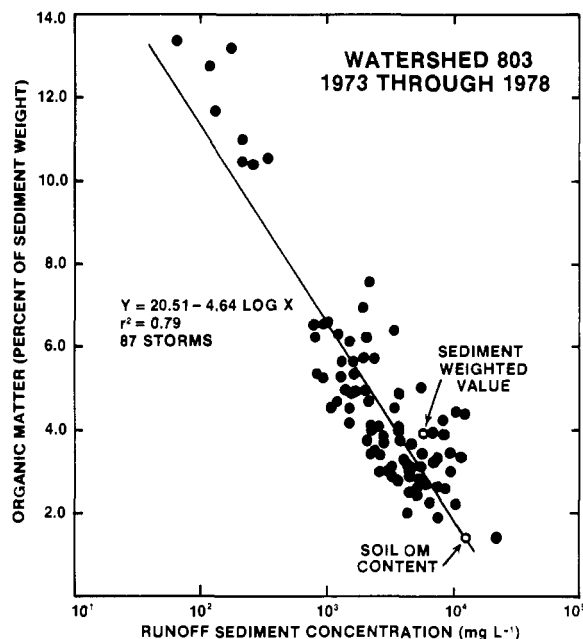


Figure 4. Percent organic matter in sediment as related to the storm sediment concentration in runoff, 1973–1978.

density, it is among the first soil components to be removed by erosion. Because of the relatively low density of OM, surface runoff from low intensity rain and/or low flow velocities is enriched in organic colloids and OM-rich clay particles (Neal, 1944; Slater, 1942; Stoltenberg and White, 1953). The discharge-weighted sediment OM content was 3.9%, as compared with the 1.6% OM content of the soil, and indicates an enrichment factor of 2.4. Thus, OM

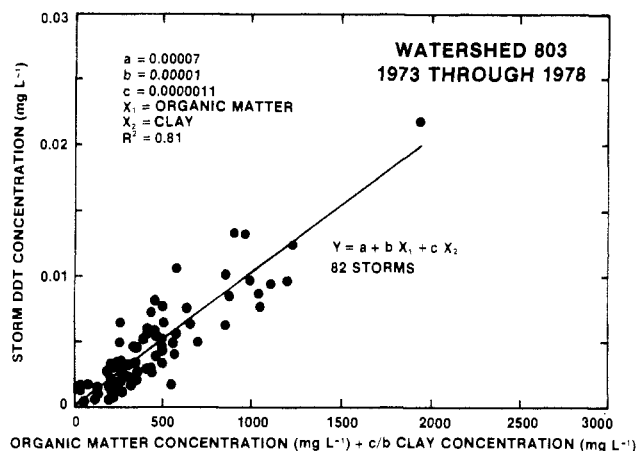


Figure 5. Storm DDT concentration (water plus sediment) as a function of sediment organic matter plus clay concentration in runoff, 1973–1978.

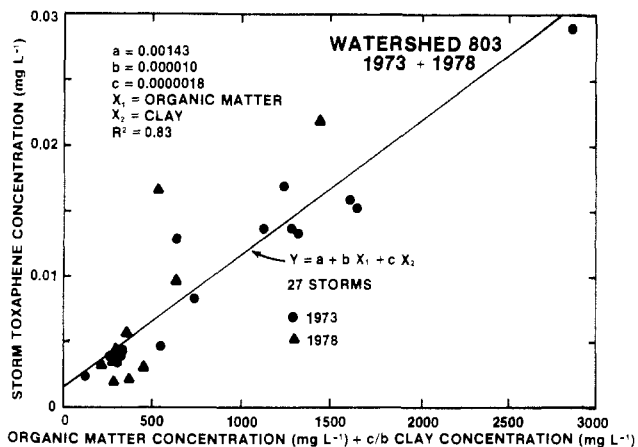


Figure 6. Storm toxaphene concentration (water plus sediment) as a function of sediment organic matter plus clay concentration in runoff, 1973 and 1978.

enrichment was somewhat greater than clay enrichment in runoff. The clay and OM enrichment factors are well within the range reported by others (Barrows and Kilmer, 1963; Massey and Jackson, 1952; Stoltenberg and White, 1953).

Pesticide Concentrations in Years When No Toxaphene or DDT Was Applied. DDT (1973–1978, Figure 5) and toxaphene (1973 and 1978, Figure 6) concentrations in runoff were linearly related to concentration of OM plus clay in runoff sediments. However, concentrations of both insecticides were nonlinearly related to sediment concentration, a result of OM enrichment at low sediment concentrations. Toxaphene, DDT, and DDE concentrations in runoff in 1973–1978 are given as functions of sediment, clay, and OM concentrations in runoff in Table IV. Toxaphene data are given for 1973 and 1978 only since those were the only years when toxaphene applications were not made. [Correlations between toxaphene and sediment concentrations in runoff for 1974 through 1977 were poor (mean $r^2 = 0.26$).] No data are presented for trifluralin because of the low correlation ($r = 0.48$) between trifluralin and sediment concentrations in runoff.

The relationships between toxaphene concentration and sediment and OM concentrations in runoff for 1973 were similar to those reported for an adjacent watershed (McDowell et al., 1981). In that report toxaphene (P , mg L^{-1}) and sediment (S , mg L^{-1}) concentrations were described by the equation

$$\log P = -4.34 + 0.71 \log S \quad r^2 = 0.94 \quad (1)$$

Table IV. Equations Describing Pesticide Concentrations (P , mg L^{-1}) in Runoff as Functions of Sediment (S), Clay (C), and Organic Matter (OM) Concentrations (mg L^{-1}) in Runoff during 1973–1978

pesticide	equation	r^2	no. of samples
toxaphene ^a	$\log P = -5.32 + 0.89 \log S$	0.78	31
	$P = 0.00247 + (2.05 \times 10^{-6})C$	0.81	27
	$P = 0.00119 + (3.96 \times 10^{-5})OM$	0.54	27
DDT	$\log P = -5.25 + 0.80 \log S$	0.72	95
	$P = 0.00067 + (1.41 \times 10^{-6})C$	0.78	81
	$P = 0.00019 + (3.00 \times 10^{-5})OM$	0.62	82
DDE	$\log P = -6.55 + 0.88 \log S$	0.72	92
	$\log P = -6.41 + 0.88 \log C$	0.67	79
	$\log P = -6.11 + 1.26 \log OM$	0.69	79

^a Toxaphene data for 1973 and 1978 only.

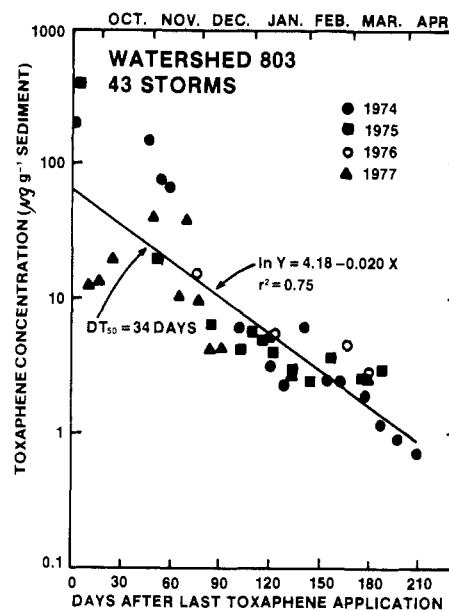


Figure 7. Decrease of toxaphene concentration in sediment during the fall, winter, and spring after summer application, 1974–1977.

and in the present report they are described by the equation

$$\log P = -5.09 + 0.81 \log S \quad r^2 = 0.97 \quad (2)$$

In both studies toxaphene concentration was a linear function of sediment OM concentration.

Toxaphene Concentrations in Years When Applied. The concentration of toxaphene in sediment decreased rapidly during September through April (after the last application in September and before the May application for cutworm control) in 1974–1977 (Figure 7). The short DT_{50} (34 days) suggests a much faster toxaphene disappearance rate at the soil surface (source of the eroded sediments) than is normally observed in bulk soil (McDowell et al., 1981). The faster disappearance probably results from greater microbiological activity (degradation, bound residues) in the soil surface zone and from photochemical degradation and volatilization, both of which are primarily surface processes (McDowell et al., 1981).

Table V. Annual Rainfall, Runoff, and Sediment and Pesticide Concentrations^a and Yields, 1973-1978

	1973	1974	1975	1976	1977	1978
rainfall, cm	163	175	147	84	103	129
runoff, cm	82	84	63	18	25	54
sediment concn, mg L ⁻¹	4780	3988	3270	4056	2000	3574
toxaphene concn, mg L ⁻¹	0.0075	0.0133	0.0209	0.0177	0.0090	0.0091
DDT concn, mg L ⁻¹	0.0054	0.0028	0.0039	0.0048	0.0031	0.0048
DDE concn, mg L ⁻¹	0.0005	0.0004	0.0005	0.0004	0.0002	0.0004
trifluralin concn, mg L ⁻¹	0.0002	0.0001	0.0004	0.0008	0.0005	0.0004
sediment yield, t ha ⁻¹	39.2	33.5	20.6	7.3	5.0	19.3
toxaphene yield, g ha ⁻¹	61.7	111.5	131.7	31.9	22.5	49.4
DDT yield, g ha ⁻¹	44.3	23.3	24.3	8.7	7.7	25.7
DDE yield, g ha ⁻¹	4.5	3.2	2.9	0.7	0.4	2.4
trifluralin yield, g ha ⁻¹	1.9	1.1	2.4	1.4	1.3	2.2

^a All concentration values are discharge weighted.

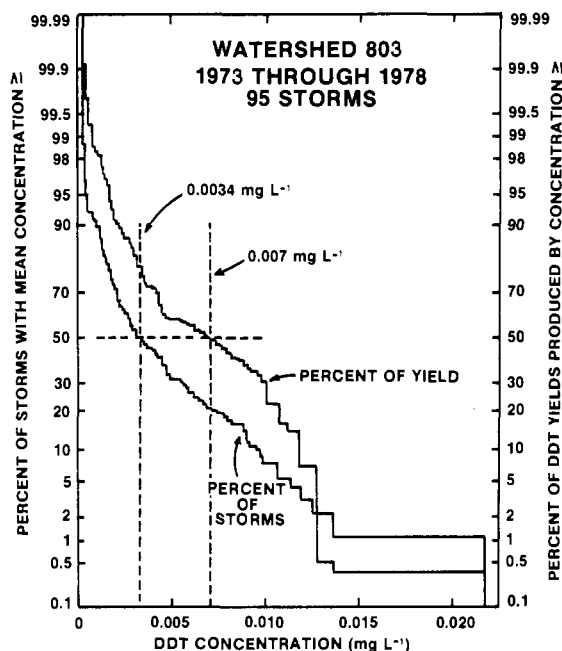


Figure 8. Cumulative (empirical) frequency distribution curves of storm DDT concentrations and yields in storm runoff, 1973-1978 (arithmetic probability).

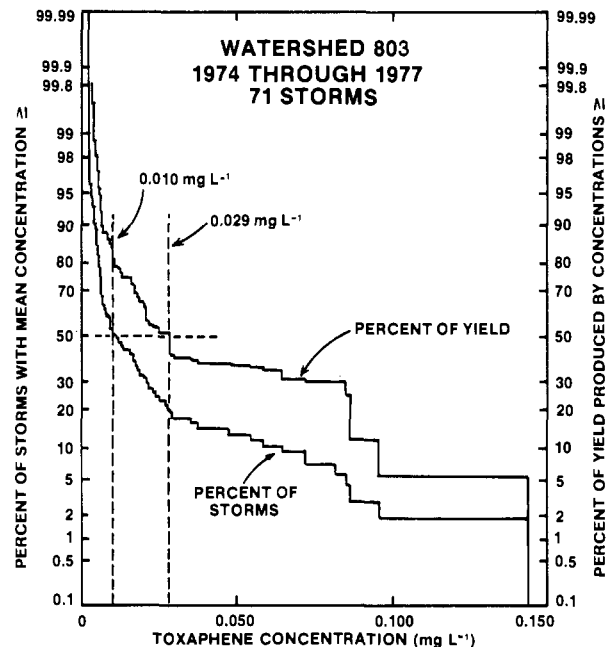


Figure 9. Cumulative (empirical) frequency distribution curves of storm toxaphene concentrations and yields, 1974-1977 (arithmetic probability).

Frequency Distributions. The cumulative frequency distributions of DDT concentrations and yields in storm runoff are shown in Figure 8. Corresponding data for toxaphene are shown in Figures 9 and 10. The data were not normally distributed and thus are presented in empirical arithmetic probability form. DDT concentrations exceeded 0.0034 mg L^{-1} in about 50% of the storms, and these storms produced 79% of the DDT yield (Figure 8). Only 20% of the storm concentrations exceeded 0.007 mg L^{-1} , but these storms produced 50% of the DDT yield. In 1974-1977, when toxaphene was applied, concentrations exceeded 0.010 mg L^{-1} in 50% of the storms, and these storms produced 80% of the toxaphene yield (Figure 9). Half the toxaphene yield was produced by only 19% of the storms (concentrations $\geq 0.029 \text{ mg L}^{-1}$). Only 5% of the storm concentrations exceeded 0.085 mg L^{-1} , but these storms produced 30% of the toxaphene yield. The differences between storm concentration distributions during years when toxaphene was applied (1974-1977) vs. years when not applied (1973 and 1978) are shown in Figure 10. Toxaphene concentrations exceeded 0.007 and 0.010 mg L^{-1} in 50% of the storms in 1973 and 1978 and 1974-1977, respectively. When no toxaphene was applied, only 3% of the storm concentrations exceeded 0.036 mg L^{-1} , whereas during application years 16% of the concentrations exceeded that value.

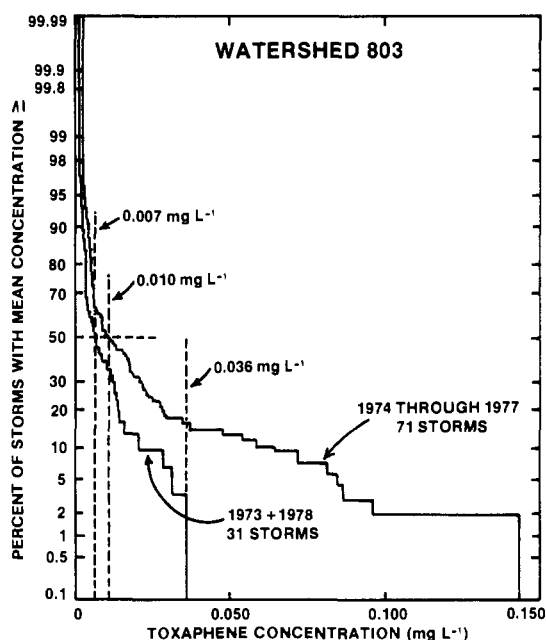


Figure 10. Comparison of cumulative (empirical) frequency distribution curves of storm toxaphene concentrations for 1973 and 1978 vs. 1974-1977 (arithmetic probability).

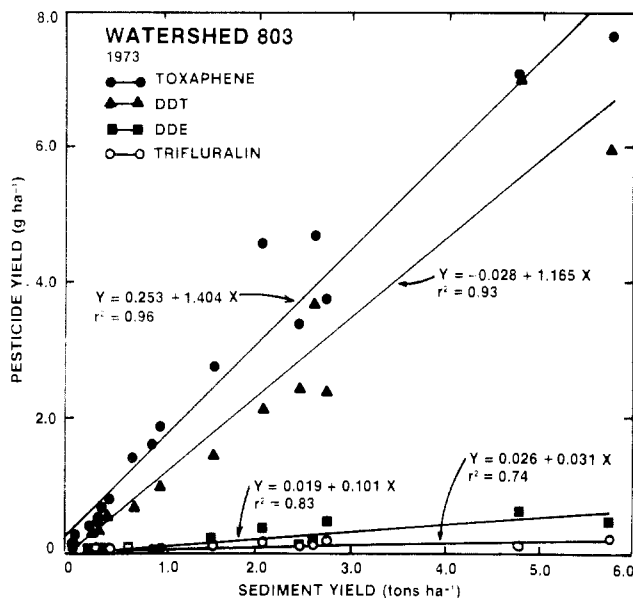


Figure 11. Pesticide yield as a function of sediment yield, 1973.

Annual Pesticide and Sediment Yields. The annual rainfall, runoff, and sediment and pesticide yields and the discharge-weighted annual sediment and pesticide concentrations in runoff are given in Table V. Annual runoff and sediment yields were best related to rainfall after stratification into periods of similar soil moisture and tillage, respectively (Murphree and Mutchler, 1981). Annual yields of DDT and DDE were linearly related to annual sediment yield ($r^2 = 0.81$ and 0.94 , respectively). As expected, annual yield of toxaphene (applied 19 times in 1974–1977) did not correlate well with annual sediment yield. As will be discussed later, toxaphene yield was closely related to sediment yield when the data for each year were analyzed according to within-year periods of similar tillage and application regimes. Because of its greater proportional distribution into the water phase (data not shown), annual trifluralin yield was poorly correlated with annual sediment yield. Mean annual pesticide and sediment concentrations were poorly correlated for all pesticides except DDE ($r^2 = 0.73$).

Storm Pesticide and Sediment Yields. Storm pesticide yields as functions of storm sediment yield for 1973 are shown in Figure 11. Storm yield for each pesticide was linearly related to storm sediment yield. Equations relating storm pesticide and sediment yields for DDT, DDE, and trifluralin in 1973–1978 and for toxaphene in 1973 and 1978 (no toxaphene applied to the watershed either year) are given in Table VI. Trifluralin was applied later than normal in 1975, and the yield data were separated into “before” and “after” application sets for statistical analysis. The equations in Table VI suggest that if erosion control is improved, pesticide amounts lost via runoff will be lower than the amounts reported, the amount of loss reduction depending upon the pesticide.

Relationships between storm toxaphene yield and storm sediment yield for the March–July, August–November, and December–February periods in 1974 are shown in Figure 12. Since no toxaphene was applied to the watershed during the March–July period, eroded soil with sorbed residues was the source of toxaphene in runoff (McDowell et al., 1981). Much of the yearly tillage (seed-bed preparation, planting, cultivation) occurred in the March–July period, during which 94 cm of rainfall produced 52 cm of runoff, 27.8 metric tons of sediment ha^{-1} , and 25 g of toxaphene ha^{-1} . These values represent 83% and 22% of the total sediment and toxaphene yields, respectively, for

Table VI. Equations Relating Storm Pesticide Yield (Y , g ha^{-1}) to Storm Sediment Yield (X , t ha^{-1})

pesticide	year	equation	r^2	no. of storms
toxaphene	1973	$Y = 0.253 + 1.40X$	0.96	18
	1978	$Y = -0.165 + 2.78X$	0.94	13
DDT	1973	$Y = -0.028 + 1.17X$	0.93	18
	1974	$Y = 0.155 + 0.55X$	0.92	13
	1975	$Y = 0.183 + 0.91X$	0.95	25
	1976	$Y = -0.010 + 1.21X$	0.87	12
	1977	$Y = -0.014 + 1.51X$	0.99	14
DDE	1978	$Y = 0.041 + 1.27X$	0.89	13
	1973	$Y = 0.019 + 0.10X$	0.83	18
	1974	$Y = -0.006 + 0.10X$	0.90	15
	1975	$Y = 0.016 + 0.11X$	0.95	21
	1976	$Y = -0.003 + 0.10X$	0.90	11
trifluralin	1977	$Y = -0.0003 + 0.08X$	0.95	14
	1978	$Y = -0.009 + 0.14X$	0.96	13
	1973	$Y = 0.026 + 0.03X$	0.74	18
	1974	$Y = -0.015 + 0.05X$	0.89	18
	1975	$Y = 0.0005 + 0.01X^a$	0.98	4
		$Y = 0.040 + 0.17X^b$	0.59	12
	1976	$Y = -0.024 + 0.24X$	0.87	10
	1977	$Y = -0.032 + 0.36X$	0.90	16
	1978	$Y = -0.035 + 0.16X$	0.55	13

^a Before 1975 trifluralin application. ^b After 1975 trifluralin application.

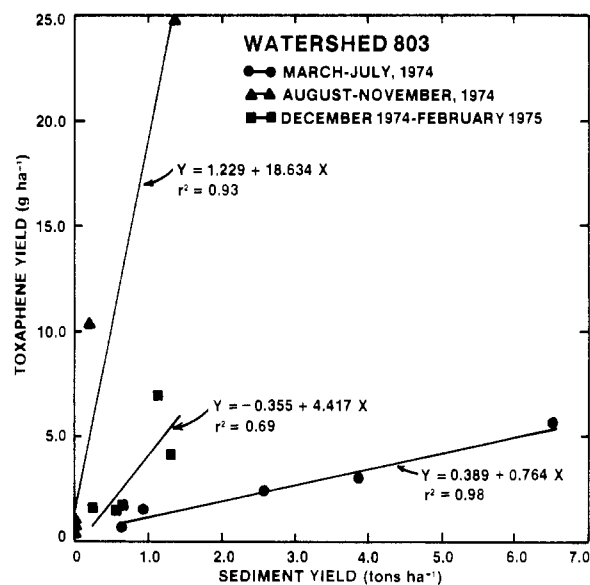


Figure 12. Toxaphene yield as related to sediment yield for different periods of the 1974 water year.

the water year. The cotton reached full canopy in late July and early August, coincident with the summer toxaphene application. The freshly sprayed plant leaves were an important source of toxaphene in runoff during August and September (Willis et al., 1982). The cotton was defoliated in October. After harvest, stalks were shredded and left as a mulch on the soil surface. Rainfall in the August–November period totaled 45 cm, producing 16 cm of runoff, 1.7 metric tons of sediment ha^{-1} , and 71 g of toxaphene ha^{-1} . These values represent 5% and 64% of the annual sediment and toxaphene yields, respectively. During Dec 1974 through Feb 1975, 36 cm of rain produced 17 cm of runoff, 3.9 metric tons of sediment ha^{-1} , and 15 g of toxaphene ha^{-1} . Similarly, within these same three periods in 1975, 1976, and 1977, toxaphene yield was linearly related to sediment yield (Table VII). The March–July tillage period in 1975 was divided into two segments since toxaphene was applied to the watershed soil in May for cutworm control.

Table VII. Equations Relating Storm Toxaphene Yield (Y , g ha^{-1}) to Sediment Yield (X , t ha^{-1}) according to Within-Year Periods, 1974-1977

year	period	equations	no. of storms	r^2
1974	March-July	$Y = 0.389 + 0.76X$	5	0.98
	Aug-Nov	$Y = 1.228 + 18.63X$	7	0.93
	Dec-Feb	$Y = -0.355 + 4.42X$	6	0.69
1975	March-April	$Y = -0.968 + 2.00X$	6	1.00
	May-July	$Y = 0.738 + 13.98X$	6	0.86
	Aug-Nov	$Y = 4.888 + 38.07X$	5	0.25
	Dec-Feb	$Y = 0.192 + 3.48X$	8	0.97
1976	March-July	$Y = 0.185 + 3.74X$	8	0.82
	Aug-Nov		0	
	Dec-Feb	$Y = 0.405 + 4.34X$	4	1.00
1977	March-July	$Y = 0.046 + 4.08X$	4	1.00
	Aug-Nov	$Y = 0.078 + 9.19X$	8	1.00
	Dec-Feb	$Y = 0.182 + 2.42X$	4	0.95

The better correlation between pesticide and sediment yields for individual storm data than for averaged annual data suggests that modeling pesticide transport on a storm basis should be superior to modeling on an averaged-annual-data basis, at least for pesticides with physicochemical properties similar to those of toxaphene and DDT. Modeling on a seasonal basis (e.g., spring tillage, summer pesticide application, etc.) may also be more accurate than modeling on an averaged-annual-data basis. Data from this study also suggest that best-management practices that reduce runoff erosion during the tillage and pesticide application seasons should reduce runoff losses of pesticides with physicochemical properties similar to those of toxaphene and DDT.

SUMMARY AND CONCLUSIONS

During 1973-1978, storm DDT, DDE, and trifluralin yields were linearly related to storm sediment yield in runoff from an 18.7-ha Mississippi Delta watershed planted to continuous cotton. Storm toxaphene and sediment yields were linearly related in 1973 and 1978, years when no toxaphene was applied to the watershed. In 1974-1977 linear relationships between toxaphene and sediment yields were evident only when each year's data were examined according to periods of similar tillage and toxaphene application regimes. Annual pesticide yield was correlated with annual sediment yield only for DDT and DDE.

In 1973-1978 clay concentration in runoff was a linear function of sediment concentration, but sediment OM concentration was a nonlinear function of sediment concentration, due to OM enrichment at low sediment concentrations. In general, DDT and DDE concentrations in 1973-1978 and toxaphene concentration in 1973 and 1978 were linear functions of sediment OM concentration and of OM plus clay concentration but were nonlinear functions of sediment concentration. In years when toxaphene and trifluralin were applied (1974-1977 and 1973-1978, respectively) their concentrations did not correlate with sediment concentration. Except for DDE, mean annual pesticide concentration did not correlate well with mean annual sediment concentration.

Soil residual pesticide concentration was not directly related to the amount applied each year. Wide ranging weather conditions probably caused variations in the relationships between loading rates and residual concentrations. The DT_{50} for DDT in 1973-1978 was 4.5 years.

The data presented in this report exhibit the same general trends as those reported earlier for toxaphene under the same climatic conditions on an adjacent watershed with soil of higher clay content. These data could be useful to modelers and those concerned with devising methods to reduce nonpoint pollution by pesticides from agricultural lands.

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Registry No. Toxaphene, 8001-35-2; DDT, 50-29-3; DDE, 72-55-9; trifluralin, 1582-09-8.

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