PREDICTING CHEMICAL MOVEMENT IN SOILS

by

George A. O'Connor
Principal Investigator
Department of Agronomy and Horticulture

and

Farhad Khorsandi
Graduate Research Assistant
Department of Agronomy and Horticulture

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ABSTRACT

Chemical Movement In Soil (CMIS) is a management/educational computer model that provides qualitative predictions of pesticide fate as a function of key soil, chemical, and climatic variables. Model assumptions limit it to nonpolar pesticides (and other xenobiotics) moving in sandy soils.

The purpose of this work was to test and modify the model for chemicals and soils pertinent to New Mexico.

Laboratory column studies with a sandy New Mexico soil matched reasonably well with model predictions. The data suggest that the model could be used as first approximations of pesticide behavior in New Mexico soils. It is primarily useful as an educational instrument for students and extension personnel examing implications of various management practices in worst-case scenarios.

Key Words: computer model, model testing, solute transport, pesticides.

INTRODUCTION

Accurate predictions of chemical movement in soils are of prime importance in the environmental management of xenobiotics, including pesticides. Knowing how a chemical behaves--how fast and to what depth it moves--and how long a compound persists in soil would increase chemical use efficiency and decrease environmental hazard. Chemical behavior in soils, however, is a complex phenomenon and predictions of that behavior usually necessitate extremely sophisticated computer models. Such models can be useful to researchers, but the model's complexity often exceeds our ability to supply needed input data and the "first approximation" needs of regulatory, monitoring or educational personnel.

Scientists and extension personnel at the University of Florida (Nofziger and Hornsby 1985) have developed a computer program useful for management and educational purposes. The model, named CMIS (Chemical Movement in Soils), provides qualitative predictions of pesticide fate as a function of key soil, chemical, and climatic variables. Model assumptions are relatively severe and restrict the model's usefulness in strict regulatory situations, but the speed and simplicity of the program have attracted considerable interest. The model has been partially verified for selected chemicals with field data in Florida (A. G. Hornsby 1985, personal communication) and in Maryland (C. Helling 1986, personal communication). The purpose of the work reported here was to test and modify the model for chemicals, soils and climatic conditions pertinent to New Mexico.

The project's objectives were to:

1. Verify model predictions of selected chemical movement in laboratory column studies; and

2. Expand the model data base to include soil, chemical and climatic data important to New Mexico;

METHODS

Laboratory column studies were conducted with the Berino fine sand. The Berino soil was chosen to represent calcareous sandy soils of New Mexico, which is low organic matter. The model was originally designed for sandy soils of Florida that satisfied model assumptions of rapid redistribution of applied water. A herbicide, 4-amino-3,5,6-trichloropicolinic acid (Picloram), was selected as the chemical of interest. Picloram has a relatively long half-life (138 days) and a small partition (adsorption) coefficient (26 mL/g OC), which makes it a highly mobile chemical. This combination of soil and chemical constituted a relatively simple, but important, test of the model predictions.

Plexiglass columns 28.5 cm long with an inside diameter of 5 cm were assembled in sections of about 2 cm each. Berino soil was packed in the columns to a bulk density of 1.54 gr/cm^3. The soil columns were initially saturated from the bottom with $0.005\underline{M}$ $CaCl_2$ and then allowed to drain to "field capacity" for at least 2 days. Except for the short irrigation periods columns were covered to minimize evaporation. A small volume of ^{14}C-picloram (.08 C) was applied to the soil surface, followed by "irrigation" with the equivalent of 1 cm of $0.005\underline{M}$ $CaCl_2$ daily. The solution infiltrated rapidly and was assumed to result in an irrigation or rainfall rate of 1 cm/d. Irrigation was continued for times predicted by the model to be sufficient to distribute the chemical throughout the top 18 cm of the column.

Columns were capped with cheese cloth at the bottom and drainage occurred when soil at the bottom of the columns reached near saturation. Because the model assumes uniform soil moisture, soil below about 18 cm did not meet model requirements and was not intended to be used in model verification.

Each soil segment was subjected to vacuum (0.3 bar) filtration to obtain a sample of the soil solution. One mL subsample of the extract was mixed with scintillation cocktail for assay by liquid scintillation counting. Corrections for quench were made by external standards ("H" number).

In addition to the control column of Berino sand, columns of Berino soil amended with sufficient sewage sludge to increase the soil's organic carbon content to 1% were prepared. Adsorption to organic matter is the primary mechanism assumed to retard chemical movement in the model. Sludge-amended soil columns thus allowed verification of the model's ability to predict chemical movement in soils with variable organic carbon contents.

RESULTS

A preliminary study was conducted to determine the moisture content distribution with depth in a Berino soil column allowed to drain for 5 days following saturation with 0.005 M $CaCl_2$. The results are given in table 1 and show that soil held significantly more water at all depths than expected if the soil had reached "field capacity" (Θ_v = 10% at 0.1 bar). Apparently, the column design allowed the soil to hold almost twice as much water as predicted. Although the moisture content varied with depth, a uniform Θ_v value of 20% was assumed for modeling purposes. A more recent version of CMIS allows for variation of soil properties with depth (CMIS layered), but was not available at the time of this work. Soil chemical properties in our study were uniform with depth and an assumed uniform moisture content of 20% was regarded as appropriate for our purposes.

Table 1. Moisture content distribution with depth--Berino soil.

Section #	Soil thickness	θ_v
	(cm)	(%)
1	0-1	12.2
2	1-3	18.6
3	3-5	19.7
4	5-7	20.2
5	7-9	22.0
6	9-11	22.3
7	11-13	22.7
8	13-15	23.8
9	15-17	25.4
		Ave. 20.8

Two columns of Berino soil were irrigated for 2 days at 1 cm/d following application of ^{14}C-picloram. Columns were sectioned and each section vacuum extracted to obtain a sample of the soil solution. Distribution of ^{14}C-picloram with depth for both columns is given in table 2. Data for both columns suggest a peak concentration in section #4 representing the 5-7 cm soil depth.

Computer simulations using an assumed uniform $\theta_v = 20\%$ predicted the "leading edge" of chemical to be at 6.3 cm after 2 days. (Simulation using $\theta_v = 10\%$ predicted the peak to be at 9.2 cm). The model assumes piston type flow and no physical or chemical dispersion (spreading) of the chemical as it flows through the soil. Thus, the "leading edge", "trailing edge" and "peak concentrations are all the same as far as the simulation is concerned. That dispersion occurs in reality is shown by the "bell-shaped" distributions in table 2. Verification of model predictions is thus arbitrary in that one could select the depth of deepest penetration depth of maximum concentration, or any point in between as representative of the "leading edge". Most scientists, however, use the depth of maximum concentration as was done herein. Results of the first column studies tend to verify the model's usefulness.

Table 2. Distribution of ^{14}C-picloram with depth-Berino soil (0.3% OC).

	Section #	Soil thickness	^{14}C-picloram
		(cm)	(dpm)
Column 1	1	0-1	297
	2	1-3	8,341
	3	3-5	31,932
	4	5-7*	41,425
	5	7-9	10,518
	6	9-11	1,128
Column 2	1	0-1	1,116
	2	1-3	10,854
	3	3-5	33,772
	4	5-7*	41,875
	5	7-9	22,567
	6	9-11	1,642

*Indicates peak concentration.

Attempts also were made to simulate picloram movement in soils with higher organic carbon content (sludge-amended soil). Experimental control in these studies was generally poor and inexperience on behalf of the experimenter resulted in data of limited value. Results of one column amended to 1% OC are nevertheless presented for discussion purposes (table 3).

Irrigation of the sludge-amended column continued for 9d, as initial model predictions suggested significant retardation of chemical movement by the increased organic carbon. The extra time involved in this experiment allowed deeper chemical movement and increased dispersion (spreading of the peak). Computer simulation predicted the leading edge to be between 15-17 cm.

Table 3. Distribution of ^{14}C-picloram with depth-Berino soil (1% OC).

Section #	Soil thickness	^{14}C-picloram
	(cm)	(d pm)
1-4	0-7	—
5	7-9	201
6	9-11	136
7	11-13	460
8	13-15	1439
9	15-17	3374
10	17-19*	3755
11	19-21	3364
12	21-23	3456
13	23-25	2699
14	25-26.5	1733

*Indicates peak concentration.

Although the prediction was reasonably good, the model fails to account for the significant spreading of chemical that is expected in nature as chemicals move deeper in soil profiles. These data emphasize the limitations of the move deeper in soil profiles. These data emphasize the limitations of the model but do not negate its usefulness as a fast, qualitative predictor of chemical behavior in soils.

The laboratory column work reported here, although simple in design and limited in scope, nevertheless appears to verify CMIS model predictions with a representative New Mexico soil. Predictions with heavier textured soils common to, for example, the Mesilla Valley are expected to be in error because redistribution of water in such soils is much slower than in sand soils for which the model was developed. Chemical mobility would be less than predicted in slowly permeable soils. Thus, the model predictions could be interpreted as representing "worst case" scenarios. Qualitative divisions of chemicals into mobile and immobile classes are useful predictions of chemical behavior and are readily made with the model.

DATA BASE EXPANSION

The model comes equipped with climatic data, soils information, and chemical characteristics pertinent to Florida. Attempts were made to expand the data base to climates, soils and chemicals pertinent to New Mexico.

Climatic data

The program requires daily effective rainfall (rainfall minus runoff) and evapotranspiration (ET) data. Daily climatic measurements are available for weather stations throughout New Mexico from the state climatologist via a computer linkage. For this study, four stations were chosen, each representing distinct regions of the state. The stations selected were: Las Cruces, Clovis, Farmington and Alcalde. Weather data for 1985 had been tabulated by the state climatologist. Data available include daily rainfall, soil and air temperature, wind speed, net radiation, and relative humidity, but not daily ET. The latter may be calculated from the other climatic data using empirical equations (eg. Penman equation). The calculations are straightforward, but tedious. Alternatively, ET may be calculated from monthly pan evaporation data summarized in annual reports for New Mexico. Unfortunately, the latter are often incomplete especially for the winter months. Calculated potential ET and pan evaporation values may be subsequently multiplied by "crop coefficients" if the predictions warrant such detail.

Chemical characteristics

The model data base includes information (partition coefficient and half-life) for 37 chemicals (herbicides, insecticides, nematicides) of importance in Florida. It was expected that at least some of these chemicals would also be important in New Mexico. The list was checked against the results of a 1983 survey of pesticide use in New Mexico (English 1985). A tabulation of the most commonly used pesticides and their characteristics is given in table 4. Chemicals of lower agricultural importance that are used by homeowners (eg. chlordane, diazinon) do not appear in table 4, but are included in the model data base.

The most prominent chemical in table 4 is 2,4-D, a herbicide that does not meet model requirements of hydrophobic, undissociated chemicals. Its adsorption is primarily to organic matter, however, and could be modeled with CMIS as a first approximation.

Chemicals with low K_{oc} values (<100) and high t1/2 values (>30) are expected to represent the greatest hazard to ground water pollution. Nematicides are designed to be mobile, persistent, and toxic, and as a group are commonly found in ground water (Sun 1986). Nationwide, EDB (ethylene dibromide) and DBCP (1,2-dibromo-3-chloropropane), and aldicarb are the most frequently reported pesticides in ground water. Fortunately, only aldicarb is used in relatively large quantities in New Mexico (table 4).

Soils data

The model requires only limited chemical and physical properties of soils, e.g., texture, bulk density, percent organic carbon, and water contents at -0.1 and -15 bars (% by volume). We hoped to obtain the information for soil series prominent in counties that included the weather station identified above. Unfortunately, the soil survey for Rio Arriba County (Alcalde station) is not completed, and so no soils information is available. Data for soils from the other counties were limited in their usefulness. If available at

Table 4. Pesticides of agricultural importance in New Mexico and their characteristics.

Common name	Chemical name	Estimated total use	Estimated acres treated	K_{oc}	t1/2
		(lbs)		(ml/g)	(d)
2,4-D	2,4-dichlorophenoxy acetic acid	204,174	204,174	20	35
Parathion	0,0-diethyl o-(p-nitrophenyl) phosphorodithioate	168,080	120,057	10,650	37
Carbofuran	2,3-dihydro-2,2-dimethyl-7 benzofuranyl methyl carbamate	142,747	118,956	29	37
Dicamba	3,6-dichloro-0-anisic acid	66,559	110,931	2	14
Atrazine	2-chloro-4(ethylamino)-6-(isopropylamino)-S-triazine	48,0004	36,926	163	48
Chloropyrifos	0,0-diethyl 0-(3,5,6-trichloro-2-pyridyl)phosphorothioate	36,897	28,382	6,070	63
Propazine	2-chloro-4,6-bis(isopropylamino)-S-triazine	27,173	33,966	154	--
Trifluralin	α,α,α-trifluro-2,6-dinitro-N-N-dipropyl-P-toluidine	20,656	29,509	14,000	70-132
Aldicarb	2-methyl-2-(methylthio) propionaldehyde-0-(methylcarbamyl)oxime	13,998	17,497	12	28
Prometryn	2,4-bis(isopropylamine)-6-(methyl thio)-6-triazine	12,617	18,024	614	--
Disulfoton	0,0-diethyl-S[2-(ethylthio) ethyl] phosphorodithioate	11,688	10,625	1,603	5
M-Parathion	0,0-dimethyl 0-(P-nitrophenyl) phosphorodithioate	7,737	8,597	5,102	4

all, data on OC content and moisture contents at 0.1 and 15 bars were often given as unacceptably wide ranges. Considerable soil analysis would have to be completed before the model could be applied to specific New Mexico soils.

Prominent soil series in counties associated with three weather stations were identified (table 5). Sandy soils, for which the model was developed, occur in parts of San Juan and Dona Ana counties, but are largely absent in Curry County. Heavier textured loams dominate the counties chosen. Chemical mobility would be over-predicted in these soils given the current assumptions in the model. More laboratory testing would be necessary to verify model predictions in these soils, but a more sophisticated model would likely be needed.

Table 5. Prominent soil series in counties associated wit selected weather stations.

County-station	Soil name	Soil series	% of county	Texture	% OC
San Juan-Farmington	Blancot-Natal	Blancot	10	Loam	--
	Association	Natal		SiCl Loam	--
	Sheppard-Mayqueen	Sheppard	4.5	L.f. Sand	<0.3
	Shiprock Complex	Mayqueen		" "	<0.3
		Shiprock		S. Loam	<0.3
	Sheppard-Huerfano	Sheppard	8.4	L.f. Sand	<0.3
	Natal Complex	Huerfano		S.Cl. Loam	--
		Natal		SiCl Loam	--
Curry-Clovis	Amarillo sandy loam		16	F.S. Loam	0.19-0.68
	Clovis sandy loam		2	S.Cl. Loam	0.30-0.58
	Amarillo loam		20	S.Cl. Loam	0.30-0.87
	Pullman loam		29	Loam	0.19-0.93
Dona Ana-Las Cruces	Wink-Puntura	Wink	9.5	S. Loam	--
	Complex	Pintura		L.f. sand	--
	Wink-Harrisburg	Wink	7.3	F.S. Loam	--
	Association	Harrisburg		S. Loam	--
		Simona		S. Loam	--
	Onite-Pujarito	Onite	4.7	S.Loam	--
	Association	Pujarito		F.S. Loam	--
		Pintura		F. Sand	--
	Bluepoint loamy sand		4.0	L. Sand	--
	Berino-Buckleban	Berino	4.1	S. Loam	--
	Association	Buckleban		C. Loam	--
		Dona Ana		S. Loam	--

SUMMARY AND CONCLUSIONS

CMIS is a management/educational model that provides qualitative predictions of pesticide fate as a function of key soil, chemical and climatic variables. Model assumptions currently limit it to nonpolar pesticides (and other xenobiotics) moving in sandy soils. The program has received widespread acceptance, principally by extension personnel, because of its speed and ease of handling.

Limited verification of the model has been reported with selected field data in Florida, Georgia and Maryland. Laboratory column studies with a sandy New Mexico soil also matched reasonably well with model predictions. These data suggest that the model could be used as first approximations of pesticide behavior in sandy New Mexico soils.

Attempts to expand the model's data base to other soils, climate and chemicals important to New Mexico were only partially successful. Chemicals important to New Mexico agriculture were identified and can be modeled with CMIS. Most of the chemicals so identified are already included in the model's data base.

Climatic data for four regions (weather stations) were examined. Model inputs of daily rainfall and ET are only partially available. ET data would have to be calculated in a tedious process or could be obtained from monthly open pan records. These records are incomplete for some stations and are largely useless for modeling purposes as pan evaporation exceeds rainfall in almost every month at every station. No movement of chemical is predicted to occur under such conditions. Thus, dryland agriculture represents a "safe" environment for the application of most pesticides given "normal" rainfall conditions, moderately deep ground water and moderately- to short-lived chemicals.

Irrigated conditions, of course, represent a very different situation. Given an irrigation efficiency of 50% and a crop with a consumptive use of about 30 in/yr., sizeable quantities of water may percolate below the root zone of sandy soils to reach the ground water. If the soil's "field capacity" were 30%, 15 inches of water could be expected to wet to a depth of 15/0.30 = 50 inches in one season.

No attempt was made to modify CMIS to handle such irrigated conditions in this short project period. Future work should concentrate on typical irrigated scenarios if pesticide contamination of ground water in New Mexico is to be simulated reasonably.

Adequate soils data for the model were largely unavailable. Serious attempts to simulate chemical movement in New Mexico will require determining soil characteristics for regions to be modeled. It is important to recall that CMIS was designed for sandy soils. Many important agricultural areas of the state are dominated by heavier textured soils. Rather than try to modify CMIS for such soils, its developers suggest slightly more sophisticated management models (Hornsby 1986, personal communication). Such models are currently under study in Florida and New York state).

CMIS may nevertheless be useful in New Mexico both as an educational instrument for students and extension personnel and as a tool examining the implications of various management practices in "worst case" scenarios. Examples of such calculations are given in Appendix A for the behavior of four chemicals in two soils with different organic carbon contents and different hydraulic properties. Chemicals include the extremely mobile, short-lived

Dicamba; the mobile, extremely short-lived 2,4-D; the mobile, moderately-lived Carbofuran; and the extremely immobile, moderately-lived Parathion. Simulations were conducted with two Florida soils using Florida climatic data (rainfall >>ET).

The simulation data are presented to demonstrate the educational value of the model, e.g. shows how chemical half-life and partition coefficient affect movement. Further interpretation is left to the reader.

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APPENDIX A

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Simulation of Chemical Movement in Soil

Chemical Data:
    Common Name                               : DICAMBA
    Trade Name                                : BANVEL D
    Partition Coefficient (ml/g OC)           : 2
    Half-Life (days)                          : 14

Soil Data:
    Soil Name                                      : ORANGEBURG FINE SANDY LOAM
    Soil Identifier                                : S37-8-(1-6)
    Percent Organic Carbon                         : 0.31 *
    Water Content at -0.1 bar (% by vol.)          : 30.3
    Water Content at -15 bars (% by vol.)          : 15.8
    Bulk Density (g/cc)                            : 1.61

Root Depth: 30 centimeters

Rainfall File             : LOCAL83.R
Evapotranspiration File: LOCAL83.ET

Starting Date  :  1 -  2 -   83
Stopping Date  :  3 - 29 -   83

Total Rainfall:                       54.74 centimeters
Total Evapotranspiration:             25.83 centimeters
Potential Evapotranspiration:         25.83 centimeters

Month   Day   Year      Rainfall  Solute Depth  Relative Mass    Elapsed Time
                        ----- centimeters ----                       Days
  1  -   2 -   83         0.84         2.7           1.00              0
  1  -   3 -   83         1.73         8.2           0.95              1
  1  -  20 -   83         0.71         8.2           0.41             18
  1  -  21 -   83         3.76        18.6           0.39             19
  1  -  23 -   83         0.58        19.7           0.35             21
  1  -  27 -   83         0.51        19.8           0.29             25
  1  -  28 -   83         1.78        25.0           0.28             26
  1  -  30 -   83         0.30        25.2           0.25             28
Chemical Movement Below Root Zone
  2  -   2 -   83         5.08        39.7           0.22             31
  2  -   6 -   83         1.02        39.7           0.18             35
  2  -  13 -   83         1.12        39.7           0.13             42
  2  -  14 -   83         5.77        54.7           0.12             43
  2  -  17 -   83         0.25        54.7           0.10             46
  2  -  23 -   83         1.45        54.7           0.08             52
  2  -  28 -   83         0.43        54.7           0.06             57
  3  -   1 -   83         1.78        54.7           0.06             58
  3  -   6 -   83         5.92        62.7           0.04             63
  3  -   7 -   83         7.54        86.0           0.04             64
  3  -  16 -   83         1.09        86.0           0.03             73
  3  -  17 -   83         4.14        90.9           0.03             74
  3  -  18 -   83         2.11        96.7           0.02             75
  3  -  21 -   83         2.11       100.3           0.02             78
  3  -  24 -   83         0.84       100.3           0.02             81
  3  -  27 -   83         3.89       107.6           0.02             84
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Simulation of Chemical Movement in Soil

Chemical Data:
     Common Name                            : DICAMBA
     Trade Name                             : BANVEL D
     Partition Coefficient (ml/g OC)        : 2
     Half-Life (days)                       : 14

Soil Data:
     Soil Name                                      : TAVARES FINE SAND
     Soil Identifier                                : S27-8-(1-6)
     Percent Organic Carbon                         : 0.09 *
     Water Content at -0.1 bar (% by vol.)          : 8.2
     Water Content at -15 bars (% by vol.)          : 0.9
     Bulk Density (g/cc)                            : 1.55

Root Depth: 30 centimeters

Rainfall File           : LOCAL83.R
Evapotranspiration File: LOCAL83.ET

Starting Date  :  1 -  2 -   83
Stopping Date  :  3 - 29 -   83

Total Rainfall:                      54.74 centimeters
Total Evapotranspiration:            22.06 centimeters
Potential Evapotranspiration:        25.83 centimeters

Month  Day  Year      Rainfall  Solute Depth  Relative Mass   Elapsed Time
                      ----- centimeters ----                       Days
  1  -   2 -   83       0.84        9.9          1.00              0
  1  -   3 -   83       1.73       29.7          0.95              1
  1  -  20 -   83       0.71       29.7          0.41             18
Chemical Movement Below Root Zone
  1  -  21 -   83       3.76       54.2          0.39             19
  1  -  23 -   83       0.58       56.2          0.35             21
  1  -  27 -   83       0.51       56.2          0.29             25
  1  -  28 -   83       1.78       73.3          0.28             26
  1  -  30 -   83       0.30       73.3          0.25             28
  2  -   2 -   83       5.08      125.4          0.22             31
  2  -   6 -   83       1.02      125.4          0.18             35
  2  -  13 -   83       1.12      125.4          0.13             42
  2  -  14 -   83       5.77      180.9          0.12             43
  2  -  17 -   83       0.25      180.9          0.10             46
  2  -  23 -   83       1.45      180.9          0.08             52
  2  -  28 -   83       0.43      180.9          0.06             57
  3  -   1 -   83       1.78      180.9          0.06             58
  3  -   6 -   83       5.92      224.8          0.04             63
  3  -   7 -   83       7.54      310.8          0.04             64
  3  -  16 -   83       1.09      310.8          0.03             73
  3  -  17 -   83       4.14      342.8          0.03             74
  3  -  18 -   83       2.11      364.1          0.02             75
  3  -  21 -   83       2.11      377.2          0.02             78
  3  -  24 -   83       0.84      377.2          0.02             81
  3  -  27 -   83       3.89      404.2          0.02             84
```

```
Simulation of Chemical Movement in Soil

Chemical Data:
    Common Name                       : 2,4-D
    Trade Name                        :
    Partition Coefficient (ml/g OC)   : 20
    Half-Life (days)                  : 5

Soil Data:
    Soil Name                                : ORANGEBURG FINE SANDY LOAM
    Soil Identifier                          : S37-8-(1-6)
    Percent Organic Carbon                   : 0.31*
    Water Content at -0.1 bar (% by vol.)    : 30.3
    Water Content at -15 bars (% by vol.)    : 15.8
    Bulk Density (g/cc)                      : 1.61

Root Depth: 30 centimeters

Rainfall File          : LOCAL83.R
Evapotranspiration File: LOCAL83.ET

Starting Date  :  1 -  2 -   83
Stopping Date  :  3 - 29 -   83

Total Rainfall:                     54.74 centimeters
Total Evapotranspiration:           25.83 centimeters
Potential Evapotranspiration:       25.83 centimeters

Month  Day  Year     Rainfall  Solute Depth  Relative Mass   Elapsed Time
                     ----- centimeters ----                      Days
  1  -   2 -   83       0.84         2.1           1.00             0
  1  -   3 -   83       1.73         6.3           0.87             1
  1  -  20 -   83       0.71         6.3           0.08            18
  1  -  21 -   83       3.76        15.0           0.07            19
  1  -  23 -   83       0.58        15.9           0.05            21
  1  -  27 -   83       0.51        16.3           0.03            25
  1  -  28 -   83       1.78        20.3           0.03            26
  1  -  30 -   83       0.30        20.6           0.02            28
Chemical Movement Below Root Zone
  2  -   2 -   83       5.08        32.1           0.01            31
  2  -   6 -   83       1.02        32.1           0.01            35
  2  -  13 -   83       1.12        32.1           0.00            42
  2  -  14 -   83       5.77        43.7           0.00            43
  2  -  17 -   83       0.25        43.7           0.00            46
  2  -  23 -   83       1.45        43.7           0.00            52
  2  -  28 -   83       0.43        43.7           0.00            57
  3  -   1 -   83       1.78        43.7           0.00            58
  3  -   6 -   83       5.92        50.0           0.00            63
  3  -   7 -   83       7.54        68.1           0.00            64
  3  -  16 -   83       1.09        68.1           0.00            73
  3  -  17 -   83       4.14        71.9           0.00            74
  3  -  18 -   83       2.11        76.4           0.00            75
  3  -  21 -   83       2.11        79.2           0.00            78
  3  -  24 -   83       0.84        79.2           0.00            81
  3  -  27 -   83       3.89        84.8           0.00            84
```

```
Simulation of Chemical Movement in Soil

Chemical Data:
    Common Name                        : 2,4-D
    Trade Name                         :
    Partition Coefficient (ml/g OC)    : 20
    Half-Life (days)                   : 5

Soil Data:
    Soil Name                                 : TAVARES FINE SAND
    Soil Identifier                           : S27-8-(1-6)
    Percent Organic Carbon                    : 0.09 *
    Water Content at -0.1 bar (% by vol.)     : 8.2
    Water Content at -15 bars (% by vol.)     : 0.9
    Bulk Density (g/cc)                       : 1.55

Root Depth: 30 centimeters

Rainfall File          : LOCAL83.R
Evapotranspiration File: LOCAL83.ET

Starting Date  :  1 -  2 -   83
Stopping Date  :  3 - 29 -   83

Total Rainfall:                     54.74 centimeters
Total Evapotranspiration:           22.06 centimeters
Potential Evapotranspiration:       25.83 centimeters

Month  Day  Year      Rainfall  Solute Depth  Relative Mass   Elapsed Time
                      ----- centimeters ----                      Days
  1  -   2 -   83       0.84        7.6           1.00             0
  1  -   3 -   83       1.73       23.0           0.87             1
  1  -  20 -   83       0.71       23.0           0.08            18
Chemical Movement Below Root Zone
  1  -  21 -   83       3.76       46.3           0.07            19
  1  -  23 -   83       0.58       47.9           0.05            21
  1  -  27 -   83       0.51       47.9           0.03            25
  1  -  28 -   83       1.78       61.1           0.03            26
  1  -  30 -   83       0.30       61.1           0.02            28
  2  -   2 -   83       5.08      101.3           0.01            31
  2  -   6 -   83       1.02      101.3           0.01            35
  2  -  13 -   83       1.12      101.3           0.00            42
  2  -  14 -   83       5.77      144.1           0.00            43
  2  -  17 -   83       0.25      144.1           0.00            46
  2  -  23 -   83       1.45      144.1           0.00            52
  2  -  28 -   83       0.43      144.1           0.00            57
  3  -   1 -   83       1.78      144.1           0.00            58
  3  -   6 -   83       5.92      178.0           0.00            63
  3  -   7 -   83       7.54      244.3           0.00            64
  3  -  16 -   83       1.09      244.3           0.00            73
  3  -  17 -   83       4.14      269.0           0.00            74
  3  -  18 -   83       2.11      285.4           0.00            75
  3  -  21 -   83       2.11      295.6           0.00            78
  3  -  24 -   83       0.84      295.6           0.00            81
  3  -  27 -   83       3.89      316.4           0.00            84
```

```
Simulation of Chemical Movement in Soil

Chemical Data:
    Common Name                              : CARBOFURAN
    Trade Name                               : FURADAN
    Partition Coefficient (ml/g OC)          : 29
    Half-Life (days)                         : 37

Soil Data:
    Soil Name                                    : ORANGEBURG FINE SANDY LOAM
    Soil Identifier                              : S37-8-(1-6)
    Percent Organic Carbon                       : 0.31
    Water Content at -0.1 bar (% by vol.)        : 30.3
    Water Content at -15 bars (% by vol.)        : 15.8
    Bulk Density (g/cc)                          : 1.61

Root Depth: 30 centimeters

Rainfall File            : LOCAL83.R
Evapotranspiration File: LOCAL83.ET

Starting Date  :  1 -  2 -   83
Stopping Date  :  3 - 29 -   83

Total Rainfall:                     54.74 centimeters
Total Evapotranspiration:           25.83 centimeters
Potential Evapotranspiration:       25.83 centimeters

Month  Day  Year      Rainfall  Solute Depth  Relative Mass   Elapsed Time
                      ----- centimeters ----                      Days
  1  -   2 -   83       0.84         1.9          1.00             0
  1  -   3 -   83       1.73         5.7          0.98             1
  1  -  20 -   83       0.71         5.8          0.71            18
  1  -  21 -   83       3.76        13.7          0.70            19
  1  -  23 -   83       0.58        14.6          0.67            21
  1  -  27 -   83       0.51        14.9          0.63            25
  1  -  28 -   83       1.78        18.6          0.61            26
  1  -  30 -   83       0.30        18.8          0.59            28
  2  -   2 -   83       5.08        29.3          0.56            31
  2  -   6 -   83       1.02        29.3          0.52            35
  2  -  13 -   83       1.12        29.3          0.46            42
Chemical Movement Below Root Zone
  2  -  14 -   83       5.77        39.9          0.45            43
  2  -  17 -   83       0.25        39.9          0.42            46
  2  -  23 -   83       1.45        39.9          0.38            52
  2  -  28 -   83       0.43        39.9          0.34            57
  3  -   1 -   83       1.78        39.9          0.34            58
  3  -   6 -   83       5.92        45.5          0.31            63
  3  -   7 -   83       7.54        61.8          0.30            64
  3  -  16 -   83       1.09        61.8          0.25            73
  3  -  17 -   83       4.14        65.2          0.25            74
  3  -  18 -   83       2.11        69.2          0.25            75
  3  -  21 -   83       2.11        71.7          0.23            78
  3  -  24 -   83       0.84        71.7          0.22            81
  3  -  27 -   83       3.89        76.8          0.21            84
```

```
Simulation of Chemical Movement in Soil

Chemical Data:
    Common Name                          : CARBOFURAN
    Trade Name                           : FURADAN
    Partition Coefficient (ml/g OC)      : 29
    Half-Life (days)                     : 37

Soil Data:
    Soil Name                                 : TAVARES FINE SAND
    Soil Identifier                           : S27-8-(1-6)
    Percent Organic Carbon                    : 0.09 *
    Water Content at -0.1 bar (% by vol.)     : 8.2
    Water Content at -15 bars (% by vol.)     : 0.9
    Bulk Density (g/cc)                       : 1.55

Root Depth: 30 centimeters

Rainfall File           : LOCAL83.R
Evapotranspiration File: LOCAL83.ET

Starting Date  :  1 -  2 -   83
Stopping Date  :  3 - 29 -   83

Total Rainfall:                     54.74 centimeters
Total Evapotranspiration:           22.06 centimeters
Potential Evapotranspiration:       25.83 centimeters

Month   Day  Year      Rainfall  Solute Depth  Relative Mass   Elapsed Time
                       ----- centimeters ----                      Days
  1   -   2 -   83       0.84        6.8           1.00              0
  1   -   3 -   83       1.73       20.7           0.98              1
  1   -  20 -   83       0.71       20.7           0.71             18
Chemical Movement Below Root Zone
  1   -  21 -   83       3.76       43.0           0.70             19
  1   -  23 -   83       0.58       44.4           0.67             21
  1   -  27 -   83       0.51       44.4           0.63             25
  1   -  28 -   83       1.78       56.3           0.61             26
  1   -  30 -   83       0.30       56.3           0.59             28
  2   -   2 -   83       5.08       92.4           0.56             31
  2   -   6 -   83       1.02       92.4           0.52             35
  2   -  13 -   83       1.12       92.4           0.46             42
  2   -  14 -   83       5.77      130.7           0.45             43
  2   -  17 -   83       0.25      130.7           0.42             46
  2   -  23 -   83       1.45      130.7           0.38             52
  2   -  28 -   83       0.43      130.7           0.34             57
  3   -   1 -   83       1.78      130.7           0.34             58
  3   -   6 -   83       5.92      161.2           0.31             63
  3   -   7 -   83       7.54      220.7           0.30             64
  3   -  16 -   83       1.09      220.7           0.25             73
  3   -  17 -   83       4.14      242.9           0.25             74
  3   -  18 -   83       2.11      257.6           0.25             75
  3   -  21 -   83       2.11      266.7           0.23             78
  3   -  24 -   83       0.84      266.7           0.22             81
  3   -  27 -   83       3.89      285.4           0.21             84
```

```
Simulation of Chemical Movement in Soil

Chemical Data:
    Common Name                          : PARATHION
    Trade Name                           : THIOPHOS
    Partition Coefficient (ml/g OC)      : 10650
    Half-Life (days)                     : 35

Soil Data:
    Soil Name                                     : TAVARES FINE SAND
    Soil Identifier                               : S27-8-(1-6)
    Percent Organic Carbon                        : 0.09 ←
    Water Content at -0.1 bar (% by vol.)  : 8.2
    Water Content at -15 bars (% by vol.)  : 0.9
    Bulk Density (g/cc)                           : 1.55

Root Depth: 30 centimeters

Rainfall File          : LOCAL83.R
Evapotranspiration File: LOCAL83.ET

Starting Date  :  1 -  2 -   83
Stopping Date  :  3 - 29 -   83

Total Rainfall:                      54.74 centimeters
Total Evapotranspiration:            22.06 centimeters
Potential Evapotranspiration:        25.83 centimeters

Month  Day  Year      Rainfall  Solute Depth  Relative Mass   Elapsed Time
                      ----- centimeters ----                      Days
  1  -   2 -   83       0.84        0.1           1.00             0
  1  -   3 -   83       1.73        0.2           0.98             1
  1  -  20 -   83       0.71        0.2           0.70            18
  1  -  21 -   83       3.76        0.5           0.69            19
  1  -  23 -   83       0.58        0.5           0.66            21
  1  -  27 -   83       0.51        0.5           0.61            25
  1  -  28 -   83       1.78        0.7           0.60            26
  1  -  30 -   83       0.30        0.7           0.57            28
  2  -   2 -   83       5.08        1.0           0.54            31
  2  -   6 -   83       1.02        1.1           0.50            35
  2  -  13 -   83       1.12        1.2           0.44            42
  2  -  14 -   83       5.77        1.5           0.43            43
  2  -  17 -   83       0.25        1.6           0.40            46
  2  -  23 -   83       1.45        1.6           0.36            52
  2  -  28 -   83       0.43        1.7           0.32            57
  3  -   1 -   83       1.78        1.8           0.32            58
  3  -   6 -   83       5.92        2.2           0.29            63
  3  -   7 -   83       7.54        2.7           0.28            64
  3  -  16 -   83       1.09        2.7           0.24            73
  3  -  17 -   83       4.14        3.0           0.23            74
  3  -  18 -   83       2.11        3.1           0.23            75
  3  -  21 -   83       2.11        3.3           0.21            78
  3  -  24 -   83       0.84        3.3           0.20            81
  3  -  27 -   83       3.89        3.6           0.19            84
```

```
Simulation of Chemical Movement in Soil

Chemical Data:
    Common Name                          : PARATHION
    Trade Name                           : THIOPHOS
    Partition Coefficient (ml/g OC)      : 10650
    Half-Life (days)                     : 35

Soil Data:
    Soil Name                                 : ORANGEBURG FINE SANDY LOAM
    Soil Identifier                           : S37-8-(1-6)
    Percent Organic Carbon                    : 0.31 *
    Water Content at -0.1 bar (% by vol.)     : 30.3
    Water Content at -15 bars (% by vol.)     : 15.8
    Bulk Density (g/cc)                       : 1.61

Root Depth: 30 centimeters

Rainfall File          : LOCAL83.R
Evapotranspiration File: LOCAL83.ET

Starting Date  :  1 -  2 -   83
Stopping Date  :  3 - 29 -   83

Total Rainfall:                    54.74 centimeters
Total Evapotranspiration:          25.83 centimeters
Potential Evapotranspiration:      25.83 centimeters

Month  Day  Year     Rainfall  Solute Depth  Relative Mass   Elapsed Time
                     ----- centimeters ----                      Days
  1  -   2 -   83       0.84        0.0           1.00             0
  1  -   3 -   83       1.73        0.0           0.98             1
  1  -  20 -   83       0.71        0.1           0.70            18
  1  -  21 -   83       3.76        0.1           0.69            19
  1  -  23 -   83       0.58        0.1           0.66            21
  1  -  27 -   83       0.51        0.2           0.61            25
  1  -  28 -   83       1.78        0.2           0.60            26
  1  -  30 -   83       0.30        0.2           0.57            28
  2  -   2 -   83       5.08        0.3           0.54            31
  2  -   6 -   83       1.02        0.3           0.50            35
  2  -  13 -   83       1.12        0.3           0.44            42
  2  -  14 -   83       5.77        0.4           0.43            43
  2  -  17 -   83       0.25        0.4           0.40            46
  2  -  23 -   83       1.45        0.5           0.36            52
  2  -  28 -   83       0.43        0.5           0.32            57
  3  -   1 -   83       1.78        0.5           0.32            58
  3  -   6 -   83       5.92        0.6           0.29            63
  3  -   7 -   83       7.54        0.8           0.28            64
  3  -  16 -   83       1.09        0.8           0.24            73
  3  -  17 -   83       4.14        0.8           0.23            74
  3  -  18 -   83       2.11        0.9           0.23            75
  3  -  21 -   83       2.11        0.9           0.21            78
  3  -  24 -   83       0.84        0.9           0.20            81
  3  -  27 -   83       3.89        1.0           0.19            84
```