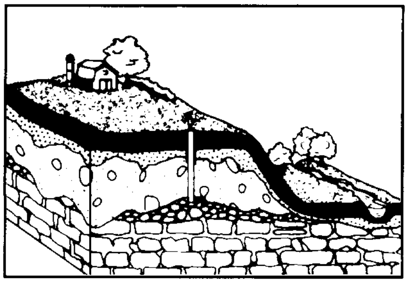

SoilFacts

Protecting Groundwater in North Carolina

A Pesticide and Soil Ranking System

Groundwater is an accumulation of water that seeps through the soil until downward movement is blocked or slowed by a barrier, such as clay or solid rock. Groundwater is the source of drinking water for more than half the people of North Carolina and nearly all its rural residents. So when many of us turn on the faucet in our homes, we are actually drawing water from this underground "pool" of accumulated water. Preventing pesticides from seeping into our groundwater is critical if we are to keep the water safe to drink.

Recent studies show that pesticides can be detected in groundwater in North Carolina, although the levels found are usually very low and below current health standards. Pesticides in groundwater may result from problems that occur when pesticides are mixed or loaded, such as spills or backsiphoning. These are "point sources," or small areas of high concentrations of pesticides that can contaminate large areas of groundwater over time. Point sources can be located and cleaned up. Good construction and maintenance of the pesticide mixing and loading area can prevent most of these problems. However, pesticides may also be making their way into ground water from fields where they were applied. By a process called leaching, some of the applied pesticide moves through the soil with water as it percolates down to groundwater.

Soil normally filters water as the water moves downward. This filtration leaves the water relatively free of contaminants by the time it reaches groundwater. Soils and pesticides both have properties that influence pesticide movement through the soil to the groundwater. These properties can be combined to rank the ability of each soil type to filter out pesticides, as well as to rank the tendency of each pesticide to leach through the soil.

In this fact sheet, we describe methods of determining soil leaching potential and pesticide leaching potential. We then use both of these values to determine the contamination potential of pesticide-soil combinations. Because the concern for leaching is greater in the coastal plain than in the piedmont or in the mountains of North Carolina, we focus on the soils of the coastal plain.

Soil Properties and Leaching Potential

The following soil properties affect pesticide leaching:

Organic Matter (OM)

When plant and animal material decomposes in or on the soil, a small part of the material remains in the soil as very slowly degradable organic matter. This soil organic matter binds most pesticides very effectively, so the more organic matter in the soil, the less likely a pesticide will leach through the soil.

Texture

The percentage of sand, silt, and clay in a soil determines its texture. Soil texture influences how fast water can move through soil. The more sand there is in the soil, the easier it is

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for water and any contaminants to move to groundwater.

Acidity (pH)

Soil acidity, or pH, affects the chemical properties of many pesticides. As soil pH decreases, pesticides bind more to the clay in the soil and are filtered out of the percolating water. Also, pesticides are usually less soluble in water at lower pH values. Acidity is more important with some types of pesticides than others and is less important overall than organic matter and texture.

Other geologic and environmental factors also affect pesticide leaching to groundwater. Depth from the soil surface to groundwater is very important. The closer the water is to the surface, the less chance there is for a pesticide to be filtered and degraded in the soil. Weather plays an important role in many ways. Pesticides break down faster in warm, moist soil than in cooler or drier soil. The timing and amount of rainfall or irrigation influence how much water percolates through the soil. If heavy rainfall or irrigation occurs soon after a pesticide application, the percolating water can carry the pesticide deep into the soil where it breaks down more slowly. Also, the type of tillage practiced can affect soil temperature, moisture, and water infiltration, all of which have an impact on pesticide degradation and leaching.

Soil Leaching Potential

The three soil properties that affect pesticide leaching—organic matter, texture, and pH—can be combined in an equation to rank soils according to their susceptibility to leaching. The following is an explanation of how we made these calculations, which are presented in Table 1.

The first step in determining soil leaching potential (SLP) is to use the value for each property to place it into a rating category. For example,

Table 1. Soil leaching potential (SLP) index values for 163 soils of the coastal plain of North Carolina and the Southeastern United States.

Soil Series	SLP Index	Soil Series	SLP Index	Soil Series	SLP Index
Alamance	75	Coxville	37	Kenansville	85
Alpin	85	Craven	61	Kureb	91
Altavista	68	Creedmoor	81	Lakeland	88
Appling	67	Croatan	2	Leaf	35
Arapahoe	44	Dare	1	Lenoir	37
Argent	52	Davidson	63	Leon	61
Augusta	68	Deloss	29	Liddell	73
Autryville	85	Dogue	65	Lignum	63
Aycock	45	Dorovan	1	Louisburg	83
Ballahack	16	Dothan	72	Lumbee	52
Bayboro	10	Dragston	80	Lynchburg	44
Baymeade	82	Duckston	93	Lynn Haven	63
Belhaven	2	Dunbar	41	Madison	60
Bibb	77	Duplin	63	Mandarin	88
Blaney	80	Durham	74	Marlboro	67
Blanton	88	Echaw	85	Marvyn	72
Bojac	84	Edneyville	69	Masada	68
Bonneau	87	Enon	67	Mayodan	68
Braddock	63	Evard	70	McColl	24
Bragg	68	Exum	67	Mecklenburg	70
Brookman	4	Faceville	64	Meggett	50
Buncombe	88	Fanin	70	Munden	84
Butters	83	Foreston	80	Nahunta	43
Byars	36	Fork	45	Nankin	60
Cainhoy	85	Fuquay	79	Nason	40
Candor	87	Gaston	58	Nimmo	81
Cape Fear	12	Georgeville	61	Norfolk	74
Caroline	68	Gilead	66	Ocilla	81
Cecil	62	Goldsboro	70	Onslow	79
Centenary	88	Goldston	80	Orangeburg	70
Chandler	52	Grantham	44	Ousley	93
Charleston	81	Grifton	56	Pacolet	60
Chastain	22	Gritney	37	Pactolus	88
Chewacla	50	Hayesville	63	Pamlico	4
Chipley	64	Helena	64	Pantego	15
Chowan	42	Herndon	61	Pasquotank	50
Clifton	59	Hyde	19	Paxville	30
Colvard	85	Invershiel	74	Pender	71
Conaby	19	Johns	74	Perquimans	50
Conetoe	85	Johnston	1	Pinkston	61
Congaree	54	Kalmia	74	Ponzer	3

[1]Index values range from 0 (no leaching potential) to 100 (maximum leaching potential).

Table 1. *(continued)*

Soil Series	SLP Index	Soil Series	SLP Index	Soil Series	SLP Index
Portsmouth	11	Toisnot	79	Weeksville	30
Pungo	1	Tomahawk	84	Wehadkee	46
Rains	46	Tomotley	47	White Store	59
Rion	74	Torhunta	21	Wickham	68
Roanoke	58	Vance	61	Wilbanks	40
Roper	8	Varina	75	Wilkes	83
Rumford	85	Vaucluse	72	Winnsboro	67
Seabrooks	88	Wagram	83	Winton	71
Stallings	82	Wahee	35	Woodington	57
State	70	Wakulla	85	Worsham	60
Stockade	25	Wando	93	Yaupon	71
Tarboro	88	Wasda	13	Yonges	54
Tate	69	Watauga	72		
Tatum	62	Wedowee	67		

[1]Index values range from 0 (no leaching potential) to 100 (maximum leaching potential).

a soil with an organic matter content of more than 2 percent would have a rating of 10, the highest. The rating is then multiplied by an importance factor relative to leaching. The importance factors are 10, 6, and 3 for organic matter, texture, and pH, respectively. These factors are used to emphasize the relative importance of each property. Once the ratings are multiplied by the importance factor for each property, the numbers are added to obtain the SLP, as in the following equation:

Soil Leaching Potential (SLP) = Organic Matter + Texture + pH

The SLP values for many coastal plain soils of North Carolina and the southeastern United States are given in Table 1.

Pesticide Properties and Leaching Potential

Pesticides have several properties that affect their ability to leach to groundwater, as follows:

K_{oc}

This property refers to how tightly and quickly the pesticide binds to organic particles in the soil. A higher number indicates a greater tendency for the pesticide to bind to organic matter and a lesser tendency to leach with the soil water.

Persistence ($T_{1/2}$)

Pesticides are degraded primarily by sunlight, soil microbes, and chemicals in the soil. The combination of these factors determines persistence, or how long the pesticide remains in the soil. Persistence is usually measured in terms of half-life ($T_{1/2}$), or the time it takes for half of the applied chemical to break down. The greater the persistence of a pesticide, the more likely it is to leach to groundwater.

Rate of Application (R)

Different amounts of each pesticide are required to control target weeds, insects, or diseases. Generally, the chance of leaching increases when pesticides are applied at a higher rate.

Application Method (F)

Pesticides may be incorporated into the soil by mixing, applied to the soil surface, or applied to growing plants. To leach through the soil, a chemical first has to reach the soil. Pesticides applied to plants can be absorbed by the plant or broken down by sunlight, reducing the potential for leaching. Pesticides applied to the soil surface can also be broken down by sunlight before reaching the soil surface. Of the three methods of application, soil incorporation provides the greatest opportunity for leaching because all of the chemical is placed in the soil.

Pesticide Leaching Potential

The pesticide properties previously described are combined in the following equation to estimate their impact on leaching potential:

$$\text{Pesticide Leaching Potential (PLP)} = (T_{1/2} \times R \times F)/K_{oc}$$

where

$T_{1/2}$ = Persistence of the pesticide, measured as half-life in days

R = Rate of application (pounds of active ingredient per acre)

F = Fraction of pesticide reaching the soil during application (1 for soil applications, less for postemergent applications, depending on row width and canopy size)

K_{oc} = Affinity for soil organic matter

The PLP index has been calculated for most pesticides registered for use in North Carolina. The results are presented in Table 2. The rate of application used to calculate PLP is the median of the range recommended by extension specialists in North Carolina.

Table 2. Typical pesticide leaching potential (PLP) index values calculated using commonly reported K_{oc}, $T_{1/2}$, and R values, and estimated fraction hitting the soil.

Common Name	Trade Name	Application[a] Method	PLP[b] Index
Herbicides:			
Acifluorfen	Blazer	f	40
Alachlor	Lasso	s	52
Ametryn	Evik	s	50
		f	46
Amitrole	Amitrole-T	f	53
Asulam	Asulox	f	51
Atrazine	AAtrex	f, pH7	56
		s, pH7	60
		s, pH5	52
		s, pH7, noncrop	66
		s, pH5, noncrop	57
Benefin	Balan	s	28
Bensulfuron	Londax	s, pH7	16
		s, pH5	4
Bensulide	Betasan	f, pH7	54
		f, pH5	39
Bentazon	Basagran	f	50
Bromacil	Hyvar	s, noncrop	84
Bromoxynil	Buctril	f	27
Butylate	Sutan	s	46
Cacodylic acid	Radecate	f	17
Chloramben	Amiben	s	64
Chlorimuron	Classic	f	17
		s, pH7	21
		s, pH5	19
Chlorpropham	Chloro-IPC	s	51
Chlorsulfuron	Glean	f	42
		s	47
Clomazone	Command	s	43
Clopyralid	Stinger	f	53
Cyanazine	Bladex	f, pH7	50
		s, <pH5.5	52
		s, >pH6.5	54
Cycloate	Ro-Neet	s	51
2,4-D	Weedone	f	45
2,4-DB	Butryac	f	33
Dalapon	Dalapon	f, noncrop	87
Desmedipham	Betanex	f	29
Dicamba	Banvel	f	58
		f	74
Dichlorprop	DP-Amine	f	49
Diclofop	Hoelon	f	44
Diethatyl-ethyl	Antor	s	40
Difenzoquat	Avenge	f	9
Diphenamide	Enide	s	54
Diuron	Karmex	s	55
		s, noncrop	62
DSMA	Methar-30	f	14
EPTC	Eptam	s	46
Ethalfluralin	Sonalan	s	25
Ethofumesate	Nortron	f	40
		s	44
Fenoxaprop	Bugle	f	27
Fluazifop	Fusilade	f	30
Fosamine	Krenite	f	9
Glyphosate	Roundup	f	23
Hexazinone	Velpar	f, noncrop	72
		s, noncrop	76
Imazapyr	Arsenal	f, noncrop	67
		s, noncrop	72
Imazaquin	Scepter	f, pH6	43
		s, pH6	48
		s, pH5	41
Imazethapyr	Pursuit	f	46
		s	50
Isopropalin	Paarlan	s	18
Lactofen	Cobra	f	22
Linuron	Lorox	s	46
MAA	Calar	f	12
MCPA	Chiptox	f	56
MCPB	Thistrol	f	58
Metolachlor	Dual	s	55
Metsulfuron	Ally	f	40
		s	44
Metribuzin	Sencor	f	44
		s	47
Molinate	Ordram	s	52
Napropamide	Devrinol	s	46
Napthalam	Alanap	s	62
Norflurazon	Zorial	s	49

[a]s = soil application and f = foliar application of pesticide. pH is given where differences have a known effect and data are available. Noncrop indicates differences in rates, usually higher than crop uses.

[b]PLP values range from 0 (no leaching potential) to 100 (maximum leaching potential).

Table 2. *(continued)*

Common Name	Trade Name	Application[a] Method	PLP[b] Index
Oryzalin	Surflan	s	39
Oxyfluorfen	Goal	s	9
Paraquat	Gramoxone	f	5
Pebulate	Tillam	s	47
Pendimethalin	Prowl	s	29
Phenmedipham	Betanal	f	26
Picloram	Tordon	f, noncrop	76
		s, noncrop	80
Prodiamine	Rydex	s	12
Prometon	Pramitol	s, pH7, noncrop	80
		s, pH5, noncrop	73
Prometryn	Caparol	s, pH7	51
		s, pH5	46
Pronamide	Kerb	f	36
Propachlor	Ramrod	s	48
Propanil	Stam	f	24
Propazine	Milogard	s, pH7	58
		s, pH5	51
Pyrazon	Pyramin	s	53
Quizalofop	Assure	f	27
Sethoxydim	Poast	f, pH7	24
		f, pH4	16
Siduron	Tupersan	f	53
		s	57
Simazine	Princep	s, pH7	60
		s, pH5	53
Sulfometuron	Oust	f	39
		s	44
Terbacil	Sinbar	s, noncrop	73
		s	58
Terbutryn	Igran	f	32
		s	36
Thifensulfuron	Pinnacle	f	12
Thiobencarb	Bolero	s	42
Triallate	Far-Go	s	34
Triclopyr	Garlon	f, noncrop	69
Tridiphane	Tandem	f	18
Trifluralin	Treflan	s	28
Vernolate	Vernam	s	41
Growth Regulators:			
Daminozide	Alar	f	50
Flumetralin	Prime Plus	f	8
Mepiquat	Pix	f	1
MH	Royal MH	f	61
NAA	Fruitone	f	42
Thiadiazuron	Dropp	f	29
Fungicides:			
Dodine	Dodine	f	16
Mancozeb	Dithane-M45	f	35
Maneb	Dithane-M22	f	26
Metalaxyl	Ridomil	f	50
		s	54
Zineb	Dithane-Z78	f	36
Insecticides:			
Aldicarb	Temik	s	71
Carbaryl	Sevin	f	32
Carbofuran	Furadan	f	66
		s	70
Chlorpyrifos	Lorsban	f	23
		s	27
Diazinon	Spectracide	s	44
Disulfoton	Di-Syston	s	42
Ethoprophos	Mocap	s	60
Malathion	Malathion	f	11
Methylparathion	Penncap	f	9
Naled	Dibrom	f	23
Terbufos	Counter	s	31

[a]s = soil application and f = foliar application of pesticide. pH is given where differences have a known effect and data are available. Noncrop indicates differences in rates, usually higher than crop uses.

[b]PLP values range from 0 (no leaching potential) to 100 (maximum leaching potential).

Groundwater Contamination Potential

The potential of a pesticide to leach into groundwater results from a combination of the soil and pesticide properties described previously in this fact sheet. The groundwater contamination potential (GWCP) index was developed to rank the relative risk of applying a specific pesticide to a specific soil (Table 3). To use the GWCP, first determine the dominant soil series for a field and find its SLP number from Table 1. Then list the pesticide alternatives for handling the weed, insect, or disease problems for the crop planned for that field and find their PLP numbers from Table 2. Finally, go to Table 3 and match the SLP category for your soil to the PLP categories for your pest control alternatives. If all other factors are equal, choose the least "risky" pesticide to handle your problem.

Table 3. Groundwater contamination potential (GWCP) risk of pesticide-soil combinations. Obtain numbers for SLP and PLP for your soil and pesticide from Tables 1 and 2, respectively.

Pesticide Leaching Potential (PLP) Rating	Soil Leaching Potential (SLP) Rating				
	0-19 Very Low	20-39 Low	40-59 Moderate	60-79 High	80-100 Very High
0-19 Very Low	Very Low Risk	Very Low Risk	Very Low Risk	Low Risk	Low Risk
20-39 Low	Very Low Risk	Low Risk	Low Risk	Moderate Risk	Moderate Risk
40-59 Moderate	Very Low Risk	Low Risk	Moderate Risk	High Risk	High Risk
60-79 High	Low Risk	Moderate Risk	High Risk	Very High Risk	Very High Risk
80-100 Very High	Low Risk	Moderate Risk	High Risk	Very High Risk	Very High Risk

For example, assume that your field contains Norfolk and Goldsboro soils, and that you plan to grow soybeans. According to Table 1, the SLP values for Norfolk and Goldsboro soils are 74 and 70, respectively. These soils fall into the "High" SLP category of Table 3. You decide that you can use alachlor (Lasso), pendimethalin (Prowl), or trifluralin (Treflan) as a preplant, incorporated weed-control strategy. In Table 2, the PLP index is 52 for alachlor, 29 for pendimethalin, and 28 for trifluralin. The PLP ratings in Table 3 for these three pesticides are "Moderate," "Low," and "Low," respectively. Lastly, to rate alachlor on this soil, use Table 3. Look down the "High" column for SLP and across the "Moderate" row for PLP to obtain "High Risk" as the GWCP rating. For pendimethalin or trifluralin, look down the same "High" SLP column and across the "Low" PLP row to get "Moderate Risk." So using either pendimethalin or trifluralin instead of alachlor reduces the risk of groundwater contamination for these two soil types.

This procedure is one part of an overall approach to preventing pesticides from contaminating groundwater. Other Best Management Practices (BMPs), such as proper handling, storage, and disposal of pesticides and their containers, and integrated pest management, are also part of the preventive approach. A complete BMP program that includes all these elements is critical to protect the groundwater on which we all depend.

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