Table 3. Combining the PC value and half-life of a pesticide to determine its potential to contaminate groundwater by leaching

Partition Coefficient (PC)	Half-life	Groundwater Contamination Potential
small	long	high
small	short	moderate
large	short	low

Pesticide Selection And Use

Agricultural use of pesticides should be part of an integrated pest management (IPM) strategy that includes biological and cultural control, pest monitoring, crop rotation, and other applicable practices. When a pesticide is needed, its selection should be based on site characteristics and the pesticide's effectiveness, toxicity to non-target species, costs, half-life, and PC value.

In review, when considering the impact on groundwater, half-lives and partition coefficients are particularly important in these cases:

(1) When the application site of a pesticide has soils with low organic-matter content,

(2) when the site is underlain with very permeable subsoil or a high water table, or

(3) when fractured or porous bedrock is located at a shallow depth beneath the application site.

Pesticides with intermediate to large PC values and short half-lives would be best in these situations because they are retained in the soil and degrade fairly rapidly. Pesticides with large PC values and long half-lives also would be retained in the soil, but the long half-life means they are likely to build-up in the soil and carry over to succeeding crops.

Soluble pesticides with small PC values and moderate to long half-lives are the least effective in protecting groundwater because they can leach easily and degrade slowly.

Remember, an important purpose of the pesticide container's label is to instruct users how to apply the pesticide safely and with minimum threat to non-target areas, such as surface water or groundwater. Pesticide users are responsible for following label instructions. It is unsafe and unlawful not to do so.

For More Information

Pesticide recommendations for various crops and pests can be obtained from your county Cooperative Extension Service office. In addition, the University of Illinois Extension Service provides pesticide use information in these publications:

Illinois Pest Control Handbook. Available for $10 from the Agricultural Publications Office, 54 Mumford Hall, 1301 W. Gregory Drive, Urbana, IL 61801. (There is a 10 percent discount for 10 or more publications and a 20 percent discount for 50 or more publications.) Make checks payable to the University of Illinois.

Illinois Pesticide Applicator Study Guide (Revised), Special Publication Number 39. Available for $2.50 from the Office of Agricultural Entomology, 172 Natural Resources Building, 607 E. Peabody Drive, Champaign, IL 61820. Make checks payable to the University of Illinois.

The Toxicity of Herbicides, Agronomy Facts W-24. (M. McGlamery and D. Anderson). One copy is available for no charge from the Department of Agronomy, N305 Turner, 1102 S. Goodwin, Urbana, IL 61801. Multiple copies cost 10 cents apiece. Make checks payable to the University of Illinois.

Prepared by Thomas J. Bicki, University of Illinois Extension Pedologist. Edited by Doug Peterson, Extension communications specialist.

Issued in furtherance of Cooperative Extension work, Acts of May 8 and June 30, 1914, in cooperation with the Department of Agriculture, WILLIAM R. OSCHWALD, Director, Cooperative Extension Service, University of Illinois at Urbana-Champaign.

February, 1988/5M
Land and Water number 12

Half-Life

Persistence is routinely expressed as a "half-life." Each half-life measures the amount of time it takes for one-half of the original amount of pesticide in the soil to be *deactivated*, or lose its ability to work effectively. However, half-life can also be defined as the time required for half of the applied pesticide to be completely *degraded*, or broken down.

Typically, a half-life based on degradation of a pesticide is longer than a half-life based on deactivation. This is especially true if toxic or nontoxic metabolites accumulate in the soil during the degradation process.

Table 1 lists some of the pesticides used in Illinois and groups them by persistency, or length of half-life. This half-life is based on their *deactivation* in soils, not degradation.

Solubility

Probably the single most important property influencing a pesticide's movement with water is its solubility, or ability to dissolve in water.

When a pesticide enters the soil, some of it will adhere to soil particles (particularly organic matter) through a process called "adsorption," and some of it will dissolve and mix with the water between soil particles. In addition, as more water enters the soil through rain or irrigation, the adsorbed pesticide may become detached from soil particles through a process called "desorption."

The solubility of a pesticide and its adsorption (attachment) to soil particles are inversely related. This means that as solubility increases, its adsorption decreases.

Partition Coefficient

One of the most useful ways to measure the adsorption of pesticides to soils is with the "partition coefficient," or PC value. The PC value is defined as the ratio of the pesticide bound to soil particles to the pesticide dissolved in the soil water.

The larger the PC value, the more strongly the pesticide attaches to soil and organic matter; and the smaller the PC value, the more likely it will dissolve in soil water. Pesticides with smaller PC values are more likely to be leached than those with larger PC values.

Table 2 lists the partition coefficients for an array of pesticides.

Estimating Pesticide Loss

When evaluating the potential of a particular pesticide to contaminate the environment, it is essential to consider its partition coefficient and half-life jointly.

For example, a pesticide with a small PC value (less than 100) and a long half-life (more than 100 days) poses a considerable threat to groundwater through leaching.

On the other hand, a nonvolatile pesticide with a large PC value (say, 1,000 or more) and a long half-life is likely to remain on or near the soil surface, increasing its chances of being carried to a lake or stream in sediment runoff.

If a pesticide has a short half-life (less than 30 days), the possibility of it polluting groundwater depends primarily on permeability, the depth to the water table, and whether heavy rain or irrigation occurs soon after application. Without water to move them, pesticides with short half-lives remain in the biologically active root zone of the soil and may degrade rapidly.

In terms of groundwater quality, pesticides with intermediate to large PC values and short half-lives may be considered "safest." They do not leach into the soil easily and they degrade fairly rapidly.

Table 3 outlines the potential for groundwater contamination according to a pesticide's PC value and half-life. A more precise prediction of pesticide loss requires complex computer models that consider site-specific information on soils, crops, and climate.

Table 2. Partition coefficients (PC) for selected pesticides

Pesticide generic name (trade name)	PC	Pesticide generic name (trade name)	PC
Dicamba (Banvel)	11	Prometone (Conquer, Pramitol)	300
Aldicarb (Temik)	12	Diuron (Karmex, Krovar, Velpar)	383
Chloramben (Amiben)	13	Propachlor (Ramrod)	420
Picloram (Tordon)	26	Diazinon (Spectracide)	580
Carbofuran (Furadan)	29	Chlorpropham (Furloe)	589
2,4-D	32	Linuron (Lorox)	863
Captan	33	Lindane (Lintox, Silvanol)	1,161
Terbacil (Sinbar)	46	Malathion (Cythion)	1,797
Fonofos (Dyfonate)	68	Phorate (Thimet)	3,200
Dinoseb (Premerge)	120	Terbufos (Counter)	4,796
Monuron (Urox)	132	Chloroxuron (Tenoran)	4,986
Simazine (Princep, Aquazine)	138	Methylparathion	7,079
Atrazine (AAtrex)	163	Parathion (Thiophos)	7,161
Dichlobenil (Casoron)	164	Dieldrin	8,400
Cyanazine (Bladex)	168	Chloropyrifos (Lorsban)	13,490
Alachlor (Lasso)	190	Trifluralin (Treflan)	14,000
Propazine (Milogard)	207	Heptachlor	24,000
Carbaryl (Sevin)	229	Chlordane	38,000
		DDT	243,000

volatilize and enter the atmosphere; it may be broken down into less toxic compounds by microbes and chemical reactions; it may be leached or moved out of the plant's root zone by rain or irrigation water filtering through the soil; or it may be carried away in runoff water on the soil surface or carried away while attached to eroding sediment.

There are three basic ways that properly applied pesticides may reach surface water and groundwater – runoff, run-in, and leaching.

Runoff is the physical transport of pollutants over the soil surface by rainwater that does not soak into the soil. Pesticides move from fields while dissolved in runoff water or "adsorbed" (chemically attached) to eroded sediment.

Run-in is the physical transport of pollutants directly to groundwater. For example, this can occur in areas of Karst-carbonate (limestone) aquifers, which contain sinkholes and porous or fractured bedrock. Rain or irrigation water can carry pesticides through sinkholes or fractured bedrock directly into groundwater.

Leaching is the movement of pollutants through the soil by rain or irrigation water, as the water moves downward through the soil. Soil organic matter content, clay content, and permeability all affect the potential for pesticides to leach in soils. In general, soils with moderate-to-high organic matter and clay content, and moderate or slow permeability are less likely to leach pesticides into groundwater. Scientists believe that "macropores," which are principally root channels and worm holes, may contribute to the leaching of pesticides in fine-textured soils.

In many areas of Illinois, pesticide runoff may be a more serious problem than either pesticide run-in or leaching. Leaching is more likely to occur in sandy, permeable soils along rivers, and run-in may occur in carbonate aquifers in northern and southern Illinois, but runoff can occur throughout the state.

The ultimate fate of a pesticide applied to soil depends largely on its persistence and solubility.

Persistence

Persistence is the ability of a pesticide to resist degradation or breakdown. Over time, most pesticides break down as the result of several chemical and microbiological reactions in the soils.

Generally, chemical reactions will only partially break down or deactivate a pesticide. Soil microorganisms, on the other hand, can *completely* break down or degrade many pesticides, changing them to carbon dixoide, water, and other inorganic compounds.

In addition, some pesticides break down into intermediate substances known as "metabolites" – substances that can sometimes still pose an environmental threat.

Because populations of microbes decrease rapidly below the root zone, pesticides leached beyond this depth are less likely to be degraded. However, some pesticides will continue to be degraded by chemical reactions after they leave the root zone.

Table 1. Grouping of pesticides based on persistence in soils

Non-Persistent (half-life less than or equal to 30 days)	Moderately Persistent (half-life greater than 30 days, less than 100 days)	Persistent (half-life greater than or equal to 100 days)
Herbicides generic name (trade name)	**Herbicides generic name (trade name)**	**Herbicides generic name (trade name)**
Alachlor (Lasso)	Acifluorfen (Blazer, Tackle)	Bromacil (Hyvar)
Bifenox (Modown)	Atrazine (AAtrex)	Fluchloralin (Basalin)
Butylate (Sutan+, Genate Plus)	Bentazon (Basagran)	Paraquat (Gramoxone)*
Chlorpropham (Furloe)	Chloramben (Amiben)	Picloram (Tordon)
Cyanazine (Bladex)	Ethalfluralin (Sonolan)	Terbacil (Sinbar)
Dicamba (Banvel)	Glyphosate (Roundup, Kleenup)*	
Dalapon (Dowpon)	Linuron (Lorox, Linex)	
Dinoseb (Premerge)	Metolachlor (Dual)	
EPTC (Etam, Eradicane, Genep)	Metribuzin (Sencor, Lexone)	
Propachlor (Ramrod)	Oryzalin (Surflan)	
Tridiphane (Tandem)	Pendimethalin (Prowl)	
Vernolate (Vernam, Reward)	Simazine (Princep, Aquazine)	
2,4-D	Triclopyr (Garlon)	
	Trifluralin (Treflan)	
Insecticides, Fungicides and Nematicides	**Insecticides, Nematicides**	**Insecticides**
Aldicarb (Temik)	Carbaryl (Sevin)	Chlordane
Captan	Carbofuran (Furadan)	Dieldrin
Diazonon(Spectracide)	Chlorpyrifos (Lorsban)	Heptachlor
Malathion	Endrin	Lindane (Isotox, Silvanol)
Phorate (Thimet)	Fonofos (Dyfonate)	
	Parathion (Niram, Parathion)	

*These pesticides have no herbicidal activity when adsorbed (chemically attached) to soil clay particles and organic matter. They are present but inactivated.

Land&Water

Conserving Natural Resources in Illinois

University of Illinois at Urbana - Champaign, College of Agriculture, Cooperative Extension Service

Pesticides And Groundwater

Pesticides As Potential Pollutants

Pesticide Use

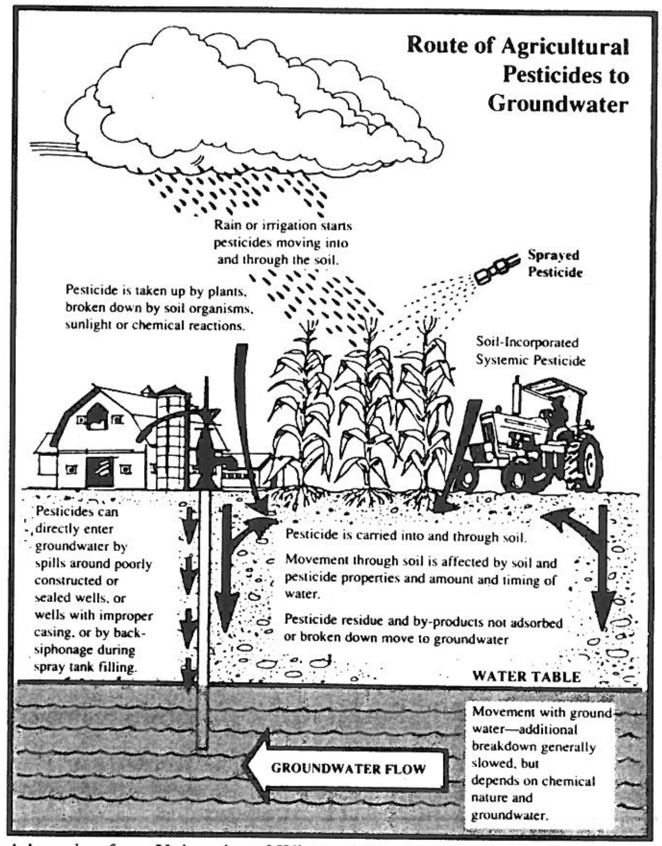
Pesticides stand out as one of the major developments of modern agriculture. They are widely used on row crops in Illinois to increase yields, save energy and labor, and make crop production efficient and profitable.

A 1985 University of Illinois pesticide-use survey estimated that of 11.7 million acres of Illinois cropland planted to corn, 99 percent were treated with herbicides and 44 percent were treated with insecticides. Of an estimated 9 million acres of soybean cropland, 97 percent were treated with herbicides and 1 percent were treated with insecticides. Annual pesticide usage was estimated at more than 49 million pounds of active ingredients.

Pesticides are indispensable in modern agriculture, but their use and/or misuse may lead to serious water quality problems – problems that could impair the use of water for crop and animal production or even human consumption. The impact of agricultural chemicals on surface water and groundwater quality has become an issue of national importance.

Fish kills, reproductive failure of birds, and acute illnesses in people have been all attributed to the ingestion of pesticides or exposure to pesticides...usually as the result of misapplication, careless storage, and careless disposal of unused pesticides and pesticide containers.

However, misuse of pesticides is not the only potential problem. In the last few years, groundwater contamination following normal pesticide use has been recognized as more than just an isolated problem. In 1987, more than 20 commonly used pesticides were detected in groundwater in 24 states.



Adaptation from University of Wisconsin —Extension.

In addition to potential health and environmental threats, pesticide losses from fields and contamination of non-target sites (such as surface water and groundwater) represent a monetary loss to farmers.

The purpose of this fact sheet is to provide information on how pesticides can move from the area where they are applied, and to show how this information can be used (along with other factors) to select pesticides that minimize the potential for groundwater contamination.

Pathways of Pesticide Loss

Once applied to cropland, a number of things may happen to a pesticide (see Figure 1). It may be taken up by plants and/or ingested by animals, insects, worms, or microorganisms in the soil; it may move downward in the soil and either adhere to soil particles or dissolve; it may