University of Idaho
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Quality Water for Idaho

Pesticides and Their Movement In Soil and Water

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Pesticides are one of the major technological developments of the twentieth century. During the past 30 years, however, concern has arisen about the threats they can pose to wildlife and mankind.

Pesticides have extended human longevity and improved the quality of life. Insect control programs have saved millions of lives by combatting the vectors of diseases such as malaria, yellow fever and typhus. The use of pesticides is also important in modern agriculture, for without chemicals to control various insect, weed, plant disease, nematode and rodent pests, our food supply would be inadequate, poor in quality and more expensive. Growers of high-value crops in Idaho depend on pesticides for economical crop management.

Pesticides are poisons, though, and may be dangerous when misused. Fish kills, reproductive failure in birds and acute illnesses in people have all been attributed to exposure to or ingestion of pesticides, usually as a result of use at an improper stage of crop growth, illegal use, misapplication, spills or careless disposal of unused pesticides or pesticide containers.

Both farmers and the general public desire careful management of pesticides in order to avoid contamination of our surface and ground waters. Learning about pesticide properties, soil properties and site conditions will help you understand why some pesticides have been found in groundwater while others have not and why pesticides have been found in the groundwater of some geographic areas but not of others.

Pesticide Movement

Once applied to cropland, a pesticide may be taken up by plants, adsorbed to plant surfaces, broken down by sunlight (photodegradation), or ingested by animals, insects, worms or microorganisms in the soil (Fig. 1). It may move downward in the soil and either adhere to soil particles or dissolve in soil water. The pesticide may vaporize and enter the atmosphere (volatilization) or break down via microbial and chemical pathways into less toxic compounds. Pesticides may be leached out of the root zone by rain or irrigation water or wash off the surface of the land. Pesticides applied

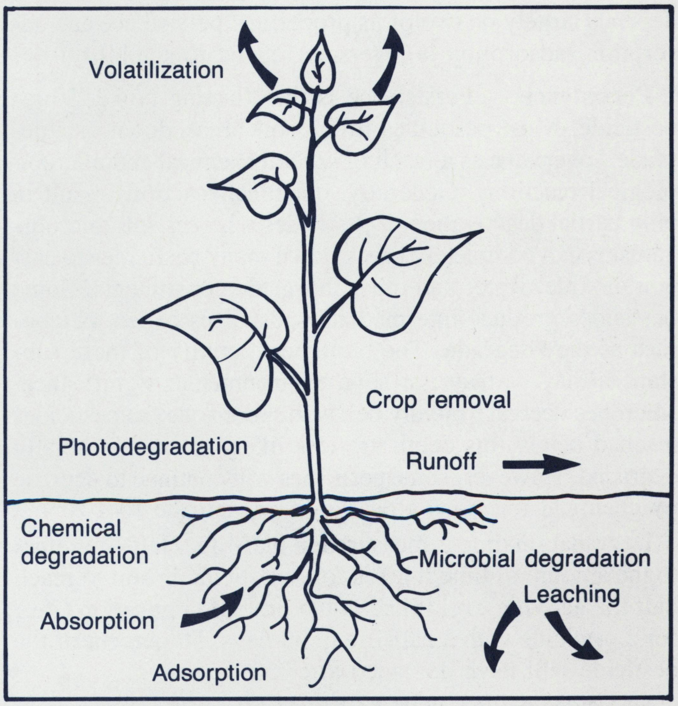

Fig. 1. Pesticide movement and degradation pathways in a soil-bedrock system.

to the soil and immediately incorporated are protected from photodegradation, volatilization and dew, which can cause hydrolysis (decomposition by reaction with water).

Properly applied pesticides can reach surface and underground waters in two ways: in runoff and by leaching. Runoff is the physical transport of pollutants (chemicals or soil) over the ground surface by rainwater, snowmelt or irrigation water that does not penetrate the soil. In the leaching process, pollutants are carried through the soil by rain or irrigation water as it moves downward. In many parts of Idaho, leaching is likely to be a more serious problem than runoff because of the permeability of our soils.

Pesticides that are susceptible to leaching do not move through all soils and into groundwater at the same rate. Six major factors determine whether a pesticide is likely to reach groundwater:

1. Pesticide properties
2. Soil properties
3. Site conditions
4. Farm management
5. Weather
6. Method of application

Pesticide Properties

The physical and chemical properties that make pesticides effective for pest control also create a potential for groundwater contamination. The fate of a pesticide applied to soil depends largely on two of its properties: persistence and adsorption (adsorption is inversely related to solubility).

Persistence — Persistence is the "lasting power" of a pesticide. Most pesticides in the soil break down or "degrade" over time as a result of several chemical and microbiological reactions. Generally, chemical reactions result in only partial deactivation of pesticides whereas soil microorganisms can completely break down many pesticides to carbon dioxide, water and other inorganic constituents. Some pesticides produce intermediate substances called metabolites as they degrade. The biological activity of these substances may or may not have environmental significance. Microbes decrease rapidly below the root zone, so pesticides leached below this depth are less likely to be microbially degraded. However, some pesticides will continue to degrade by chemical reactions after they have left the root zone.

Degradation time is measured in half-life. Half-life refers to the amount of time it takes for a pesticide in soil to reach half the activity level it had at the time of application (i.e., for a pesticide with a half-life of 30 days, 50 percent of the pesticide will have degraded after 30 days).

Pesticides having short half-lives often do not persist in the soil long enough to leach into groundwater. Chemicals with long half-lives are highly persistent and have a greater chance of leaching into groundwater.

To describe potential persistence, scientists classify pesticides as follows:

1. Non-persistent chemicals
   Half-life less than 30 days
2. Moderately persistent chemicals
   Half-life of 30 to 100 days
3. Persistent chemicals
   Half-life greater than 100 days

The persistence of selected pesticides used in Idaho are shown in Table 1.

Table 1. Pesticide persistence based on degradation half-life.

Non-persistent (<30 days)	Moderately persistent (30 to 100 days)	Persistent (>100 days)
alachlor (Lasso)	atrazine (AAtrex)	bromacil (Hyvar)
aldicarb (Temik)	azinphos-methyl (Guthion)	DBCP (Nemagon)
butylate (Sutan)	carbaryl (Sevin)	dieldrin (Alvit)
captan	carbofuran (Furadan)	diuron (Karmex)
dalapon	chlorpyrifos	lindane
dicamba (Banvel)	chlorsulfuron (Glean)	paraquat
dimethoate (Cygon)	DCPA (Dacthal)	picloram (Tordon)
disulfoton (Di-Syston)	diazinon	
fluazifop-butyl (Fusilade)	EPTC (Eptam)	
malathion	fenvalerate (Pydrin)	
metalaxyl (Apron)	fonofos (Dyfonate)	
methomyl	glyphosate (Roundup)	
methyl parathion	linuron	
oxamyl (Vydate-L)	metribuzin (Sencor)	
2,4-D	oxyfluorfen (Goal)	
	parathion	
	permethrin (Ambush)	
	phorate (Thimet)	
	pronamide (Kerb)	
	simazine (Princep)	
	terbacil (Sinbar)	
	TCA	
	triallate (Far-Go)	
	trifluralin (Treflan)	

Adsorption — The adsorption process binds pesticides to soil particles, like iron filings or paper clips stick to a magnet. Adsorption occurs because of the attraction between chemicals and soil particles. Pesticide molecules that are positively charged, for example, are attracted to and can bind to negatively charged clay particles. Strongly adsorbed pesticides are less subject to leaching through soil than weakly adsorbed pesticides. On the other hand, strongly adsorbed pesticides are more subject to loss via surface runoff (erosion) (Table 2).

Factors controlling pesticide adsorption include pesticide charge; soil pH, temperature and water content; the presence of previously adsorbed chemicals that have a stronger bond to soil particles; and the amount and type of organic matter present. In general, pesticide adsorption relates inversely to pesticide solubility in water. Highly soluble pesticides are weakly adsorbed and pose a greater threat of groundwater contamination (Table 2).

Soil Properties

Soil Permeability — Soil permeability is a measure of how fast water can move downward through the soil. Soil texture and structure control soil permeability. Soils having coarse or sandy textures are generally more permeable than loamy or clayey soils. Soils with good structure generally have larger pores and greater permeability than soils with poor structure. As soil permeability increases, the potential for pesticides to reach the groundwater by downward leaching increases.

Organic Matter— Many pesticides are adsorbed by soil organic matter, thereby reducing their rate of downward movement. Pesticide mobility and potential contamination of groundwater are greater in soils having a low organic matter content than in soils having a high organic matter content. To increase or maintain soil organic matter, add manure, reduce tillage operations and incorporate crop residues at the soil surface.

Site Conditions

Rainfall and Irrigation — Areas with high rates of rainfall or irrigation may have large amounts of water percolating (moving) through the soil, especially if there is no runoff. Under such conditions, the potential for pesticides to leach to groundwater is high, especially if the soils are highly permeable, if the soil is low in organic matter and if the pesticide is persistent and only weakly adsorbed.

To minimize the potential for leaching, avoid applying pesticides just before a heavy irrigation or rainfall. Avoid over-irrigation, especially early and late in the growing season when crops cannot take up excess water from the soil. Base irrigation frequency and amount on an assessment of the crop's water use characteristics and the soil's water-holding capacity.

Depth to Groundwater — The time it takes for pesticides to travel to groundwater decreases as the depth to groundwater decreases. Generally, the depth to groundwater is least in spring and greatest in late summer. If spring rains come shortly after pesticide application and the water table is close to the surface, a greater potential for groundwater contamination exists.

Determining the Potential for Pesticide Contamination of Groundwater

The potential for a pesticide to contaminate groundwater depends on a combination of the following:

1. Rate of pesticide application
2. Method of pesticide application
3. Pesticide persistence and mobility
4. Soil permeability and organic matter content
5. Frequency and timing of rainfall and irrigation
6. Depth to groundwater

Many of these factors vary dramatically among the northern, southwestern, southcentral, central and southeastern sections of Idaho. This diversity makes it impossible to estimate potential contamination without site-specific information for each factor. Ask your agricultural Extension agent or Soil Conservation Service personnel for this information.

Factors that lead to the greatest potential for contamination of groundwater are listed in Table 3. In sandy or gravelly soils that are low in organic matter content and underlain by shallow groundwater, avoid using chemicals that are persistent (Table 1) and mobile (Table 2). If irrigating, avoid excessive irrigation, especially when the irrigation coincides with or immediately follows a pesticide application.

Pesticide Selection and Use

Pesticides should be part of an overall agricultural pest management strategy that includes biological controls, resistant crop varieties, certified seed, cultural methods, pest monitoring and other applicable practices referred to altogether as Integrated Pest Management or IPM. When field scouting and thresholds indicate a pesticide is needed, selection should be based on effectiveness, toxicity to nontarget species, cost, adsorption (solubility), persistence and site characteristics such as soil permeability.

Some of the pesticides listed in Table 2 have severely restricted use due to acute toxicity or long half-life. An important purpose of the pesticide container's label is to instruct users to apply the pesticide safely and with minimum threat to nontarget species both on and off the application site. Pesticide users assume the responsibility to follow label instructions. To do otherwise is unsafe and unlawful.

Table 3. Factors that increase the probability of contamination of groundwater by pesticides.

Pesticide factors	Soil properties	Site conditions
Long persistence (long half-life)	Sandy or gravelly soil (high permeability)	Shallow groundwater (less than 25 feet)
High mobility (high leaching hazard)	Low organic matter content (less than 2%)	Excessive irrigation
High application rate		Heavy rainfall
Chemigation		

Need More Information?

Pesticide recommendations for various crops and pests may be obtained from the University of Idaho Cooperative Extension System. Contact your county Extension office for information.

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Table 2. (cont'd).

Pesticide[1]	Relative leachability[2]	Relative runoff potential	Detection[3]
mancozeb (Manzate, Dithane M-45)	small	large	
maneb (Dithane)	small	medium	
MCPA ester (Weedone)	small	large	
MCPA salt (Weedar)	large	small	
MCPB (Thistrol)	small	medium	
mecoprop (MCPP)	large	small	
metalaxyl (Apron)	medium	small	
metaldehyde (Metaldehyde)	small	medium	
metham (Vapam)	medium	small	
methamidophos (Monitor)	small	medium	
methazole (Probe)	small	large	
methidathion (Supracide)	small	medium	
methiocarb (Mesurol)	medium	medium	
methomyl (Lannate, Nudrin)	medium	small	yes
methyl isothiocyanate (Vorlex)	medium	small	
methyl parathion (Penncap-M)	total use is small	medium	
metiram (Polyram)	small	large	
metolachlor (Dual)	medium	medium	yes
metribuzin (Sencor, Lexone)	large	medium	yes
metsulfuron-methyl (Ally)	large	medium	
mevinphos (Phosdrin)	medium	small	
molinate (Ordram)	medium	medium	
monocrotophos (Azodrin)	large	small	
MSMA (Bueno)	small	large	
NAD or NAAm (Amid-Thin)	small	medium	
NAA ester (Tre-Hold)	small	medium	
NAA salt (Fruitone)	medium	small	
naled (Dibrom)	small	medium	
napropamide (Devrinol)	medium	large	
naptalam (Alanap L)	medium	small	
norflurazon (Evital)	medium	medium	
oryzalin (Surflan)	small	large	
oxamyl (Vydate-L)	large	small	yes
oxycarboxin (Plantvax)	large	small	
oxydemeton-methyl (Metasystox-R)	large	small	
oxyfluorfen (Goal)	small	large	
oxythioquinox (Morestan)	small	large	
paraquat (Gramoxone)	small	large	
parathion (Phoskil)	small	medium	
PCNB (Terraclor)	small	large	
pebulate (Tillam)	medium	medium	
pendimethalin (Prowl)	small	large	
permethrin (Ambush, Pounce)	small	large	
petroleum oil (Volck, Supreme or Superior oils)	small	medium	
phenmedipham (Betamix)	small	large	
phorate (Thimet)	medium	large	
phosalone (Zolone)	small	medium	
phosmet (Imidan)	small	medium	
phosphamidon (Dimecron)	large	small	
picloram (Tordon)	large	small	yes
piperalin (Pipron)	small	medium	
profenofos (Curacron)	small	large	
prometon (Pramitol)	large	large	
prometryn (Caparol)	small	medium	
pronamide (Kerb)	small	large	yes
propachlor (Ramrod)	small	medium	yes
propanil (Stam)	small	small	
propargite (Comite, Omite)	small	large	
propazine (Milogard)	large	medium	yes
propiconazole (Tilt)	medium	medium	
pyrazon (Pyramin)	large	medium	
quizalafop-ethyl (Assure)	small	large	
sethoxydim (Poast)	small	small	
siduron (Tupersan)	medium	large	
simazine (Princep)	large	medium	yes
sulfometuron methyl (Oust)	large	medium	
sulprofos (Bolstar)	small	medium	
tebuthiuron (Spike)	large	small	yes
temephos (Abate)	small	large	
terbacil (Sinbar)	large	medium	yes
terbufos (Counter)	small	medium	yes
thiobencarb (Bolero)	small	medium	
thiodicarb (Larvin)	small	medium	
thiophanate (Topsin-E)	medium	small	
thiram (Thiram)	medium	medium	
triadimefon (Bayleton)	medium	medium	
triallate (Far-Go)	small	large	
tribufos (Folex)	small	large	
trichlorfon (Dylox)	large	small	
triclopyr (Crossbow, Access, Garlon, Grazon)	medium	large	
tridiphane (Tandem)	small	large	
trifluralin (Treflan)	small	large	yes
triforine (Funginex)	small	medium	
trimethacarb (Broot)	small	medium	
vernolate (Reward, Surpass, Vernam)	medium	medium	
vinclozalin (Ronilan)	medium	medium	
ziram (Ziram)	small	medium	

[1]Names in parentheses are trade names.

[2]Actual leachability may vary depending upon site-specific conditions.

[3]A yes under the detection column indicates the chemical has been detected in groundwater somewhere in the United States.

Table 2. Pesticide mobility classification based upon leaching potential and surface runoff potential as reported by the USDA Soil Conservation Service.

Pesticide[1]	Relative leachability[2]	Relative runoff potential	Detection[3]
2,4-D acid (Dacamine)	medium	small	yes
2,4-D ester (Weedone)	small	medium	yes
2,4-D amine (Weedar)	medium	medium	yes
2,4-DB ester (Butyrac Ester)	small	medium	yes
2,4-DB amine (Butyrac)	medium	small	yes
acephate (Orthene)	small	small	
acifluorfen (Tackle, Blazer)	medium	medium	yes
alachlor (Lasso)	medium	medium	yes
aldicarb (Temik)	large	small	yes
ametryn (Evik)	medium	medium	yes
amidochlor (Limit)	small	medium	
amitraz (Mitac)	small	medium	
amitrole (Amitrol T)	medium	medium	
ancymidol (A-Rest)	medium	medium	
anilazine (Dyrene)	small	small	
assert (Assert)	large	medium	
asulam (Asulox)	medium	small	
atrazine (AAtrex)	large	medium	yes
azinphos-methyl (Guthion)	small	large	
benefin (Balan)	small	large	
benomyl (Benlate)	small	large	
bensulide (Prefar)	small	large	
bentazon (Basagran)	medium	small	yes
bromacil (Hyvar)	large	medium	yes
bromoxynil (Buctril)	small	medium	
butylate (Sutan)	small	medium	yes
carbaryl (Sevin)	small	medium	yes
carbofuran (Furadan)	large	small	yes
carboxin (Vitavax)	medium	medium	yes
chloramben (Amiben)	large	small	yes
chlorimuron ethyl (Classic)	large	small	
chloropicrin (Chlor-O-Pic)	small	small	
chlorothalonil (Bravo)	small	large	yes
chlorpyrifos (Lorsban, Dursban)	small	large	
chlorsulfuron (Glean)	large	small	
clomazone (Command)	large	medium	
clopyralid (Lontrel, Reclaim)	large	small	
cyanazine (Bladex)	medium	medium	yes
cycloate (Ro-Neet)	small	large	
cypermethrin (Cymbush, Ammo)	small	large	
cyromazine (Larvadex)	large	small	
dalapon (Basfapon)	large	small	yes
daminozide (Alar)	medium	small	
DCNA (Botran)	small	large	
DCPA (Dacthal)	small	large	
desmedipham (Betanex)	small	large	
diazinon (D.Z.N.)	large	medium	yes
dicamba (Banvel)	large	small	yes
dichlobenil (Casoron)	medium	medium	
dichloropropene (Telone)	medium	medium	yes
dichlorprop (Weedone)	small	medium	
diclofop methyl (Hoelon)	small	large	
dicofol (Kelthane)	small	large	
dicrotophos (Bidrin)	medium	small	
diethatyl ethyl (Antor)	small	medium	
difenzoquat methyl sulfate (Avenge)	small	large	
diflubenzuron (Dimilin)	total use is small	large	
dimethoate (Cygon)	medium	small	
dinocap (Karathane)	small	medium	
diquat (Diquat)	small	large	
disulfoton (Di-Syston)	small	medium	yes
diuron (Karmex)	medium	large	yes
DNOC (Elgetol)	medium	medium	
dodine (Cyprex)	small	large	
endosulfan (Thiodan)	small	large	
endothall (Des-i-cate)	small	small	
EPTC (Eptam)	medium	medium	
esfenvalerate (Asana)	small	large	
ethalfluralin (Sonalan)	small	large	
ethephon (Cerone)	total use is small	medium	
ethion (Ethion)	small	large	
ethofumesate (Nortron)	large	medium	
ethoprop (Mocap)	large	medium	
etridiazole (Terrazole)	small	large	
fenamiphos (Nemacur)	medium	medium	yes
fenarimol (Rubigan)	small	medium	
fenbutatin-oxide (Vendex)	small	large	
fenoxaprop-ethyl (Acclaim)	total use is small	large	
fenoxycarb (Logic)	small	small	
fenvalerate (Pydrin)	small	large	
ferbam (Carbamate)	medium	medium	
fluazifop-butyl (Fusilade)	small	large	
flucythrinate (Pay-Off, Cybolt)	small	large	
fluridone (Sonar)	medium	large	
fluvalinate (Mavrik)	small	large	
fomesafen (Reflex)	large	medium	
fonofos (Dyfonate)	medium	large	
formetanate (Carzol)	small	large	
fosamine ammonium (Krenite)	total use is small	medium	
fosethyl-Al (Aliette)	small	large	
glyphosate (Roundup)	small	large	
hexazinone (Velpar)	large	small	yes
hydramethylnon (Amdro)	total use is small	large	
imazaquin (Scepter)	large	small	
iprodione (Rovral)	small	medium	
isopropylamine salt of imazapyr (Arsenal, Chopper)	large	small	
lindane (Isotox)	medium	large	
linuron (Lorox)	medium	large	
malathion (Cythion)	small	small	
maleic hydrazide (Royal MH-30)	large	small	

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