ALABAMA COOPERATIVE Extension SYSTEM

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Pesticide Management To Protect Water Quality

Understanding Pesticides And How They Affect Water Quality

While pesticides are indispensable in modern agriculture, their use or misuse may lead to serious water quality problems. 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, or careless disposal of unused pesticides and pesticide containers.

Pesticide contamination of drinking water is a national concern. In the fall of 1990, EPA completed a 5-year national well water survey of community and rural wells. The results showed a much smaller detection level for pesticides than was expected: 4.2 percent in rural domestic (private) wells and 10.4 percent in community wells. Only a small portion of the wells were estimated to have at least one pesticide above the drinking water standard or maximum contaminant level (MCL): 0.8 percent or 750 community wells and 0.6 percent or 60,900 rural domestic wells.

Although this was better than expected news on pesticide contamination in groundwater, it still meant that an estimated 9,850 community wells (0.8 percent of the 94,625 community wells nationwide) and 446,000 private wells (0.6 percent of the 10,508,770 rural domestic wells nationwide) throughout the country have some pesticide contamination.

In addition to potential health and environmental threats, pesticide losses from fields and contamination of surface water and groundwater represent a monetary loss to farmers.

So how can pesticides be managed to minimize both threats to the environment and health and economic losses? The first step in safe management of pesticides is understanding how pesticides move in soils and what factors affect their movement.

Pesticide Movement In Soils

Once applied to cropland, a number of things may happen to a pesticide. It may be taken up by plants; it may be 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 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; it may be carried away in runoff water on the soil surface; or it may be transported while attached to eroding sediment.

Properly applied pesticides may reach surface water and groundwater in three basic ways: 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 or suspended 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 limestone (Karst-carbonate) 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. In fine-textured soils, macropores, which are principally root channels and wormholes, may contribute to the leaching of pesticides.

The EPA has compiled a list of leachable pesticides, which are shown in Table 1. Special restrictions have been placed on some of these chemicals and others have been discontinued.

Table 1. EPA's List Of Leachable Pesticides.

Chemical Name	Trade Names
Acephate	Orthene
Alachlor	Lasso
Aldicarb	Temik
Azinphos methyl	Guthion, Gusathion M
Bensulfide	Betasan, Prefar
Butylate	Sutan
Chloropicrin	Telone
Chlorsulfuron	Glean, Telar
Cyanizine	Bladex, Fortrol
Cycloate	Ro-Neet
2,4-D, dimethylamine salt	
Diazinon	Spectracide, Knox-Out
Dichlobenil	Casoron, Decabane, Prefix D
Dicloron	Allisan, Botran
Diethalyl ethyl	Antor
Dimethoate	Cygon, Fostion MM, Perfekthion, Rogor, Roxion
Diquat dibromide	Aquicide, Cleansweep, Pathclear, Reglone, Weedol
Disulfoton	Disyston, Dithiosystox, Frumin AL, Solvirex
EPTC	Eptam, Eradicane
Ethofumesate	Nortran, Tramat
Ethoprop	Mocap, Prophos
Fenamiphos	Nemacur
Fluometuron	Cotoran
Fonofos	Dyfonate
Fosetyl-Al	Aliette, Mikal
Hexazinone	Velpar
Linuron	Lorox, Afalon
Metalaxyl	Apron, Fubol, Ridomil
Metaldehyde	Deadline
Methiocarb	Mesurol, Draza
Methomyl	Lannate, Nudrin
Methyl isothiocyanate	Trapex
Metolachlor	Dual
Metribuzin	Lexone, Sencor
Molinate	Ordram
Napropamide	Devrinol
Naptalam, sodium salt	Alanap
Norflurazon	Evital, Solicam, Zorial
Oryzalin	Dirimal, Ryzelan, Surflan
Oxadiazon	Ronstar
Oxydemeton methyl	Metasystox R
Parathion	Bladan, Folidol, Fosferno, Niran
Pebulate	Tillam
Prometryn	Caparol, Gesagard
Propyzamide	Kerb
Sulfometuron	Oust
Tebuthiuron	Perflan, Spike
Triallate	Avadex BE, Fargo
Vernolate	Vernam

Source: Council For Agricultural Science And Technology, 1992.

Factors Affecting Pesticide Movement

How much pesticide is lost to runoff, run-in, or leaching depends on some combination of the following four important factors:

- Pesticide properties.
- Soil properties.
- Site conditions.
- Management practices.

The importance of these factors to pesticide movement varies with each situation. A single factor may be more important than another in one situation and of very little consequence in the next.

Pesticide Properties. Four chemical properties that affect pesticide movement are solubility, adsorption, volatility, and degradation.

Solubility. The tendency of a pesticide to dissolve in water affects its leaching potential. As water seeps downward through soil, it carries with it water-soluble chemicals. This process is called leaching. Water solubility greater than 30 milligrams per liter (or parts per million) has been identified as the "flag" for a potential leacher. Highly soluble pesticides have a tendency to be carried in surface runoff and to be leached from the soil to groundwater. Poorly soluble pesticides—applied to soil but not incorporated—have a high potential for loss through runoff or erosion.

Adsorption. Adsorption refers to the attraction between a chemical and soil particles. Many pesticides do not leach because they are adsorbed, or tightly held, by soil particles. Pesticides which are weakly adsorbed will leach in varying degrees depending on their solubility.

Adsorption depends not only on the chemical properties of the pesticide but also on the soil type and amount of soil organic matter present. Even strongly adsorbed pesticides can be carried with eroded soil particles in surface runoff.

The potential for a pesticide to be adsorbed is called the adsorption partition coefficient (K_d). Some example partition coefficients are shown in Table 2.

Table 2. Partition Coefficients For Selected Pesticides.

Pesticide	K_d
Aldicarb (Temik)	10
Carbofuran	29
Atrazine	172
Carbaryl (Sevin)	229
Malathion (Cythion)	1,178
Parathion	7,161
DDT	243,000

Source: McBride, 1989.

The lower the partition coefficient, the greater the pesticide leaching potential.

Volatility. The tendency of a pesticide to become a gas, similar to the evaporation of water, will affect its loss to the atmosphere by volatilization. If a pesticide is highly volatile (has a high vapor pressure) and is not very water soluble, it is likely to be lost to the atmosphere and less will be available for leaching to groundwater. Highly volatile compounds may become groundwater contaminants, however, if they are highly soluble in water. For most pesticides, loss through volatilization is insignificant compared with leaching or surface losses.

Volatile pesticides may cause water contamination or other problems from aerial drift. Environmental conditions such as temperature, humidity, and wind speed affect volatilization losses. Special surfactants or carriers can be used to reduce volatilization losses.

Degradation. A pesticide's rate of degradation (persistence) in soil also affects leaching potential. Pesticides are degraded, or broken down into other chemical forms, by sunlight (photodecomposition), by microorganisms in the soil, and by a variety of chemical and physical reactions. The longer the compound lasts before it is broken down, that is, the longer it persists, the longer it is subject to the forces of leaching and runoff.

Soil Properties. The properties of soils that affect pesticide movement are texture, permeability, and organic matter content.

Texture. Soil texture is determined by the relative proportions of sand, silt, and clay. Texture affects movement of water through soil (infiltration) and, therefore, movement of dissolved chemicals such as pesticides. The sandier the soil, the greater the chance of a pesticide reaching groundwater.

Coarse-textured sands and gravels have high infiltration capacities, and water tends to percolate through the soil rather than to run off over the soil surface or be adsorbed to soil particles. Therefore, coarse-textured soils generally have high potential for leaching of pesticides to groundwater but low potential for surface loss to streams and lakes.

On the other hand, fine-textured soils such as clays and clay loams generally have low infiltration capacities, and water tends to run off rather than to percolate. Soils with more clay and organic matter also have more surface area for adsorption of pesticides and higher populations of microorganisms to break down pesticides. Therefore, fine-textured soils have low potential for leaching of pesticides to groundwater and high potential for pesticide surface loss.

Permeability. Highly permeable soils are susceptible to leaching. Soil permeability is a measure of how fast water can move downward through a particular soil and can typically be inferred from soil texture. Since water moves quickly through highly permeable soils, these soils may lose dissolved chemicals with the percolating water. In highly permeable soil, the timing and the method of pesticide application need to be carefully designed to minimize leaching losses.

Organic Matter Content. Soils high in organic matter have a low leaching potential. Soil organic matter influences how much water a soil can hold and how well it will be able to adsorb pesticides and prevent their movement. In addition, high organic matter may reduce potential for surface loss by increasing the soil's ability to hold both water and dissolved pesticides in the root zone where they will be available to plants. High organic matter also supports much of the microbial activity that decomposes pesticides.

Site Conditions. The site conditions that affect pesticide movement are depth to groundwater, geologic conditions, topography, and climate.

Depth To Groundwater. In areas where groundwater is close to the soil surface, contamination from pesticides is a greater threat. The shallower the depth to groundwater, the less soil there will be to act as a filter and the less chance for degradation or adsorption of pesticides.

In humid regions, groundwater may be only a few feet below the surface of the soil. If rainfall is high and soils are permeable, water carrying dissolved pesticides may take only a few days to percolate downward to groundwater. In arid regions, groundwater may lie several hundred feet below the soil surface, and leaching of pesticides to groundwater may be a much slower process.

Geologic Conditions. Pesticides are more likely to leach in areas where geologic layers between the soil and groundwater are highly permeable. Highly permeable materials, such as gravel deposits, allow water and dissolved pesticides to freely percolate downward to groundwater. Layers of clay, on the other hand, are much less permeable and thus inhibit the movement of water.

Proximity of drainage ditches, streams, ponds, and lakes increases the potential for rainfall or irrigation runoff to contaminate surface water. Drainage wells, abandoned wells, and sinkholes pose similar hazards for groundwater contamination.

Table 3. Summary Of Groundwater Contamination Potential As Influenced By Pesticide Characteristics, Soil Characteristics, Site Conditions, and Management Practices.

Parameters Considered	Low Risk	High Risk
Pesticide Properties:		
Water Solubility	Low solubility	High solubility
Soil Adsorption	Highly adsorbed	Poorly adsorbed
Degradation (Persistence)	Short half-life (a few days)	Long half-life (several weeks)
Soil Properties:		
Texture/Permeability	Fine clay	Coarse sand
Organic Matter	High content	Low content
Macropores	Few, small	Many, large
Site Conditions:		
Depth To Groundwater	Deep (20 feet or more)	Shallow (10 feet or less)
Rainfall	Small volumes	Large volumes
Irrigation	Infrequently	Frequently
Management Practices:		
Application Methods	Applied to crops or soil surface	Injected or incorporated into soil
Rates	Low volume used	High volume used
Handling Practices:		
Spills	Prevented or cleaned up immediately	Ignored
Storing	In locked building with impermeable floor	On the ground, exposed to weather
Mixing	In field	Near wellhead or water supply
Washing	On impermeable rinse pad	Near well or water supply
Rinsing	Rinsate sprayed	Rinsate poured on ground near well or ditch
Back-siphoning	Prevented with check valves	Ignored
Container Disposal	Triple or pressure rinsed and recycled	Ignored

Source: McBride, 1989.

Topography. Topography, which includes the size, shape, aspect, slope steepness, and slope length of landforms, affects the general drainage characteristics of the landscape and can impact surface runoff losses of pesticides. Even slightly soluble pesticides and those strongly adsorbed to soil particles can be carried off in stormwater, especially if intense rainfall occurs shortly after application. Good soil and water conservation practices will reduce these losses. Flat landscapes, areas with closed drainage systems where water drains toward the center of a basin, and especially sinkhole areas, are more susceptible to groundwater contamination.

Climate. Areas with high rates of rainfall or irrigation may have large amounts of water percolating through the soil and, therefore, are highly susceptible to leaching of pesticides especially if the soils are highly permeable. Intensity, duration, and frequency of occurance of rainfall also affect stormwater run-off and losses of surface-applied pesticides.

Management Practices. The management practices that affect movement of pesticides are application methods, application rates and timing, and handling practices.

Application Methods. The way in which a pesticide is applied determines leaching potential. Injection or incorporation into the soil, as in the case of nematicides, makes the pesticide most readily available for leaching. Most of the pesticides which have been detected in groundwater are those which are incorporated into the soil rather than sprayed onto growing crops. Pesticides sprayed onto crops, however, are more susceptible to volatilization and surface runoff losses.

Application Rates And Timing. The rate and timing of a pesticide's application also are critical in determining whether it will leach to groundwater. The larger the amount used and the closer the time of application to a heavy rainfall or irrigation, the more likely that some pesticide will leach to groundwater. Particular care should be taken when practicing chemigation because of the risks of back-siphoning and leaching.

Handling Practices. Properly storing and mixing pesticides and properly disposing of the containers are other factors that can contribute significantly to the contamination of surface water or groundwater. Quick and proper cleanup of spills is also important.

See Table 3 for a summary of factors affecting pesticide movement.

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