33. Fate of pesticides in soil and plant.

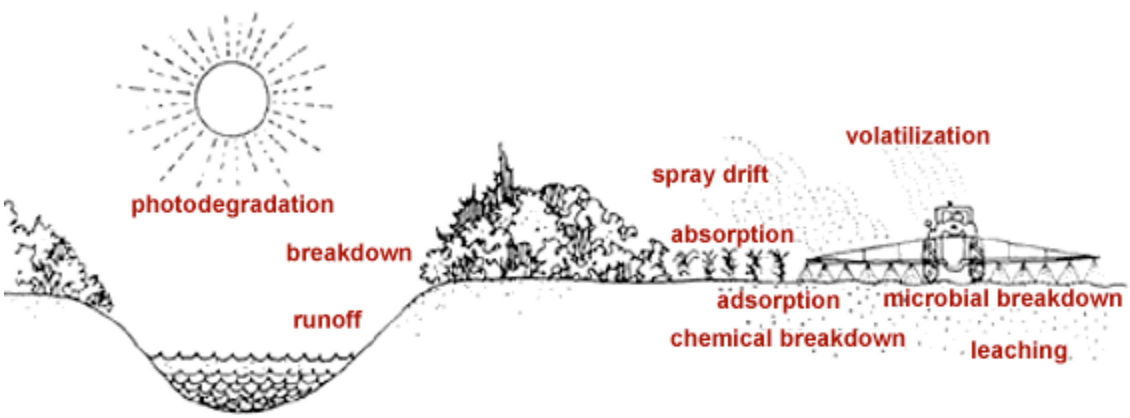
What Happens to Pesticides

When a pesticide is released into the environment many things happen to it. Sometimes what happens is beneficial. For example, the leaching of some herbicides into the root zone can give you better weed control.

Sometimes, releasing pesticides into the environment can be harmful, as not all of the applied chemical reaches the target site. For example, runoff can move a herbicide away from target weeds. The chemical is wasted, weed control is reduced, and there is more chance of damaging other plants and polluting soil and water. Or some of the pesticide may drift downwind and outside of the intended application site.

Many processes affect what happens to pesticides in the environment. These processes include adsorption, transfer, breakdown and degradation. Transfer includes processes that move the pesticide away from the target site. These include volatilization, spray drift, runoff, leaching, absorption and crop removal.

Each of these processes is explained in the following sections.



Transfer Processes

Adsorption is the binding of pesticides to soil particles. The amount a pesticide is adsorbed to the soil varies with the type of pesticide, soil, moisture, soil pH, and soil texture. Pesticides are strongly adsorbed to soils that are high in clay or organic matter. They are not as strongly adsorbed to sandy soils.

Most soil-bound pesticides are less likely to give off vapours or leach through the soil. They are also less easily taken up by plants. For this reason you may require the higher rate listed on the pesticide label for soils high in clay or organic matter.

Volatilization is the process of solids or liquids converting into a gas, which can move away from the initial application site. This movement is called vapour drift. Vapour drift from some herbicides can damage nearby crops.

Pesticides volatize most readily from sandy and wet soils. Hot, dry, or windy weather and small spray drops increase volatilization.

Where recommended, incorporating the pesticide into the soil can help reduce volatilization.

Spray Drift is the airborne movement of spray droplets away from a treatment site during application.

Spray drift is affected by:

- spray droplet size - the smaller the droplets, the more likely they will drift
- wind speed - the stronger the wind, the more pesticide spray will drift
- distance between nozzle and target plant or ground - the greater the distance, the more the wind can affect the spray

Drift can damage nearby sensitive crops or can contaminate crops ready to harvest. Drift may also be a hazard to people, domestic animals, or pollinating insects. Drift can contaminate water in ponds, streams, and ditches and harm fish or other aquatic plants and animals. Excessive drift also reduces the pesticide applied to the target and can reduce the effectiveness of a treatment.

Runoff is the movement of pesticides in water over a sloping surface. The pesticides are either mixed in the water or bound to eroding soil. Runoff can also occur when water is added to a field faster than it can be absorbed into the soil. Pesticides may move with runoff as compounds dissolved in the water or attached to soil particles.

The amount of pesticide runoff depends on:

- the slope
- the texture of the soil
- the soil moisture content
- the amount and timing of a rain-event (irrigation or rainfall)
- the type of pesticide used

Runoff from areas treated with pesticides can pollute streams, ponds, lakes, and wells. Pesticide residues in surface water can harm plants and animals and contaminate groundwater. Water contamination can affect livestock and crops downstream.

Pesticide runoff can be reduced by:

- using minimum tillage techniques to reduce soil erosion
- grading surface to reduce slopes
- diking to contain runoff
- leaving border vegetation and plant cover to contain runoff

Pesticide losses from runoff are greatest when it rains heavily right after you spray. Reduce the chances of runoff by watching the weather forecast. If heavy rain is expected, delay spraying to avoid runoff. Irrigate according to label instructions.

Leaching is the movement of pesticides in water through the soil. Leaching occurs downward, upward, or sideways. The factors influencing whether pesticides will be leached into groundwater include characteristics of the soil and pesticide, and their interaction with water from a rain-event such as irrigation or rainfall. These factors are summarized in the table below.

Leaching can be increased when:

- the pesticide is water soluble
- the soil is sandy
- a rain-event occurs shortly after spraying
- the pesticide is not strongly adsorbed to the soil

Groundwater may be contaminated if pesticides leach from treated fields, mixing sites, washing sites, or waste disposal areas.

Summary of Groundwater Contamination Potential as Influenced by Water, Pesticide and Soil Characteristics		
	Risk of Groundwater Contamination	
	Low risk	**High risk**
Pesticide characteristics		
Water solubility	low	high
Soil adsorption	high	low
Persistence	low	high
Soil characteristics		
Texture	fine clay	coarse sand
Organic matter	high	low

Macropores	few, small	many, large
Depth to groundwater	deep (100 ft or more)	shallow (20 ft or less)
Water volume		
Rain/irrigation	small volumes at infrequent intervals	large volumes at frequent intervals
Based on: McBride, D. K. 1989. Managing pesticides to prevent groundwater contamination. North Dakota State University Extension Service, Publication E-979.		

Similar factors influence pesticide movement in surface runoff, except that pesticides with low water solubility may move with surface runoff if they are strongly adsorbed to soil particles and have some degree of persistence.

Soil characteristics are important to pesticide movement. Clay soils have a high capacity to adsorb many chemicals including pesticides and soil nutrients. Sandy soils have a much lower capacity to adsorb pesticides. Organic matter in the soil also can adsorb pesticides. Soil structure influences the movement of water and pesticides. Coarse textured sandy soils with large air spaces allow more rapid movement of water than fine textured or compacted soils with fewer air spaces. Other characteristics of the site, such as depth to groundwater, or distance to surface water, are important. Finally, the pattern of water falling on the soil through irrigation or rainfall is significant. Small volumes of water at infrequent intervals are less likely to move pesticides than large volumes of water at more frequent intervals.

Absorption is the uptake of pesticides and other chemicals into plants or microorganisms. Most pesticides break down once they are absorbed. Pesticide residues may be broken down or remain inside the plant or animal and be released back into the environment when the animal dies or as the plant decays.

Some pesticides stay in the soil long enough to be absorbed by plants grown in a field years later. They may damage or leave residues in future crops.

Crop Removal through harvest or grazing may remove pesticide residues.

Degradation or Breakdown Processes

Degradation is the process of pesticide breakdown after application. Pesticides are broken down by microbes, chemical reactions, and light or photodegradation. This process may take anywhere from hours or days to years, depending on environmental conditions and the chemical characteristics of the pesticide. Pesticides that break down quickly generally do not persist in the environment or on the crop. However pesticides that break down too rapidly may only provide short-term control.

Microbial breakdown is the breakdown of chemicals by microorganisms such as fungi and bacteria.

Microbial breakdown tends to increase when:

- temperatures are warm
- soil pH is favourable
- soil moisture and oxygen are adequate
- soil fertility is good

Chemical breakdown is the breakdown of pesticides by chemical reactions in the soil. The rate and type of chemical reactions that occur are influenced by:

- the binding of pesticides to the soil
- soil temperatures
- pH levels - Many pesticides, especially the organophosphate insecticides, break down more rapidly in alkaline soils or in spray tank water with a high pH level.
- moisture

Photodegradation is the breakdown of pesticides by sunlight. All pesticides are susceptible to photodegradation to some extent. The rate of breakdown is influenced by the intensity and spectrum of sunlight, length of exposure, and the properties of the pesticide. Pesticides applied to foliage are more exposed to sunlight than pesticides that are incorporated into the soil. Pesticides may break down faster inside plastic-covered greenhouses than inside glass greenhouses, since glass filters out much of the ultraviolet light that degrades pesticides.

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Pesticide Characteristics

From University of Nebraska NebGuide G1182

Pesticide characteristics are also important in determining the fate of the chemicals in the environment. These characteristics include:

1. solubility in water (water solubility)
2. tendency to adsorb to the soil (soil adsorption)
3. pesticide persistence in the environment (half-life)

Pesticides with high water solubility, low tendency to adsorb to soil particles and long persistence or half-life have the highest potential to move into water. These three factors, soil adsorption, water solubility and persistence, are commonly used to rate pesticides for their potential to leach or move with surface runoff after application.

Soil adsorption is measured by K_{oc}, which is the tendency of pesticides to be attached to soil particles. Higher values (greater than 1000) indicate a pesticide that is very strongly attached to soil and is less likely to move unless soil erosion occurs. Lower values (less than 300-500) indicate pesticides that tend to move with water and have the potential to leach or move with surface runoff.

Water solubility is measured in parts per million (ppm) and measures how easily a pesticide may be washed off the crop, leach into the soil or move with surface runoff. Pesticides with solubilities of less than 1 ppm tend to remain on the soil surface. They tend not to be leached, but may move with soil sediment in surface runoff if soil erosion occurs. Pesticides with solubilities greater than 30 ppm are more likely to move with water.

Pesticide persistence is measured in terms of the half-life, or the time in days required for a pesticide to degrade in soil to one-half its original amount. For example, if a pesticide has a half-life of 15 days, 50 percent of the pesticide applied will still be present 15 days after application and half of that amount (25 percent of the original) will be present after 30 days. In general, the longer the half-life, the greater the potential for pesticide movement. A pesticide with a half-life greater than 21 days may persist long enough to leach or move with surface runoff before it degrades.

No one factor--adsorption, water solubility, or persistence--can be used to predict pesticide behavior. It is the interaction of these factors and their interaction with the particular soil type and environmental conditions that determines pesticide behavior in the field.

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Ways to Minimize Pesticide Impact

The following are several practices which reduce the potential for pesticides to cause environmental damage or water contamination. Consider applying these practices to your farm.

Integrated Pest Management

Follow integrated pest management (IPM) principals. IPM doesn't rely solely on chemicals for pest control. Biological control, cultural practices, and timely chemical applications are used to obtain the necessary level of control. Pesticides are the last line of defense and are used only when pest levels are causing sufficient damage to offset the expense of the application. IPM also requires the following actions:

- Scout or monitor crops regularly to check the levels of pest populations and their damage.
- Implement available non-chemical control practices, including mechanical, cultural and biological controls, sanitation, and plant resistance. For example, use crop rotation to manage corn rootworms and cut alfalfa early to manage weevils (cultural controls); select resistant varieties (plant

resistance); thoroughly clean combines between fields to reduce weed seed introductions (sanitation); and use cultivation to control weeds (mechanical control).

- Maximize the benefits of naturally occurring biological controls by using pesticides only when necessary and selecting pesticides which are the least harmful to beneficials. For example, some insecticides and fungicides kill predatory mites, which can cause a mite outbreaks later in the season.

Prevent backsiphoning and spills

Never allow a hose used for filling a spray tank to extend below the level of the water in the tank. Contain all spills as quickly as possible and handle according to label directions. Use anti-siphon devices in the water line. They are inexpensive and effective. (See the Emergencies section of this website for further spill information.)

Consider weather and irrigation plans

Application just before rainfall or irrigation may result in reduced efficacy if the pesticide is washed off the target crop, resulting in the need to reapply the pesticide.

Heavy rainfall may also cause pesticide-contaminated runoff at the application site.

Pesticide use and storage

Always read and follow the label directions on the pesticide container. Use pesticides only when economic thresholds are reached and buy only what you need. Use appropriate protective equipment and clothing according to label instructions. Avoid mixing pesticides near wells or other sources of water. Store all pesticides safely, and according to legal requirements (see the Storage and Shelf Life section of this website).

Dispose of pesticide and chemical wastes safely

Dispose of excess chemical and pesticide containers in accordance with label directions. Triple-rinse empty pesticide containers (use this water in the spray tank), punch holes in containers, and dispose of them at approved waste disposal sites. (See the Pesticide and Container Disposal section of this website for further information).

Leave buffer zones around sensitive areas

Read the pesticide label for guidance on required buffer zones around water, buildings, wetlands, wildlife habitats and other sensitive areas.

Reduce off-target drift

Never begin an application when wind or temperature favors pesticide drift to an off target area. Use appropriate spray pressure and nozzle selection to minimize drift.

Application equipment

Maintain all application equipment in good working order and calibrate it regularly.

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Summary

Many pesticides have the potential to cause harm to the environment if they are not used safely. Minimize the potential for environmental issues by following label directions, storing pesticides safely, and using them properly. Help keep groundwater free of contaminants; safeguard the health of your family, neighbors, and livestock; and ensure a clean, healthy environment by:

- Practicing Integrated Pest Management (IPM).
- Only using pesticides that are labeled for the intended crop and pest.
- Considering application site characteristics (soil texture, slope, organic matter).
- Considering the location of wells, ponds and other water bodies.
- Measuring accurately.
- Maintaining application equipment and calibrating accurately.
- Mixing and loading carefully.
- Preventing backsiphoning and spills.
- Considering the impact of weather and irrigation.
- Storing pesticides safely and securely.
- Disposing of wastes safely.
- Leaving buffer zones around sensitive areas.
- Reducing off-target drift.