Pesticides in the Environment

Applicators and the public are concerned about how pesticides may harm the environment. At first, hazards to humans were the primary reason the EPA decided to classify a pesticide as a restricted-use product. Now, more pesticide labels list environmental effects (such as contamination of groundwater or toxicity to birds or aquatic organisms) as reasons for restriction. To register new pesticides, EPA requires manufacturers to submit extensive environmental tests. The agency also reviews environmental effects when reevaluating existing pesticide registrations.

Pesticides in the Environment

The **environment** includes everything around us, the natural elements, people, the manufactured parts of our world, and the indoor areas in which we live and work. The environment is air, soil, water, plants, animals, houses, restaurants, office buildings, factories, and all that they contain. Anyone who uses a pesticide must consider how it affects the environment.

Applicators must ask:

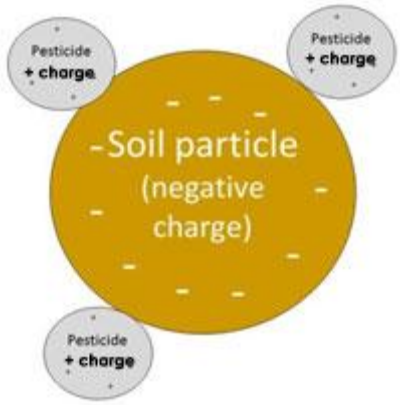
- Where will the pesticide go after it leaves its container or application equipment?
- What effects could it have on those non-target sites it may reach?
- What can I do to minimize harmful effects?

Pesticide Characteristics

You must be aware of certain physical and chemical characteristics of pesticides: solubility, adsorption, persistence, and volatility to know how they move in the environment and interact with it.

Solubility is a measure of the ability of a pesticide to dissolve in a solvent, usually water. Highly soluble pesticides dissolve easily in water. They are more likely to move with surface water in runoff or by leaching down through the soil than less soluble pesticides.

Adsorption measure how well a pesticide sticks to soil particles. It occurs because of the attraction between the chemical and soil particles. Typically, oil-soluble pesticides are more attracted to clay particles and organic matter in soil than water-soluble pesticides. Also, pesticide molecules with a positive (+) charge are tightly adsorbed to negatively (-) charged soil particles. A pesticide that adsorbs to soil particles is less likely to move from the spray site than one that does not adsorb tightly to soil.



Positively charged pesticide particles adsorbed to negatively charged soil particle

Persistence is the ability of a pesticide to remain present and active in its original form for a long time before breaking down. Persistence is described in terms of "half-life": the time needed for 50% of the chemical to break down (degrade). The longer the half-life, the more persistent the pesticide.

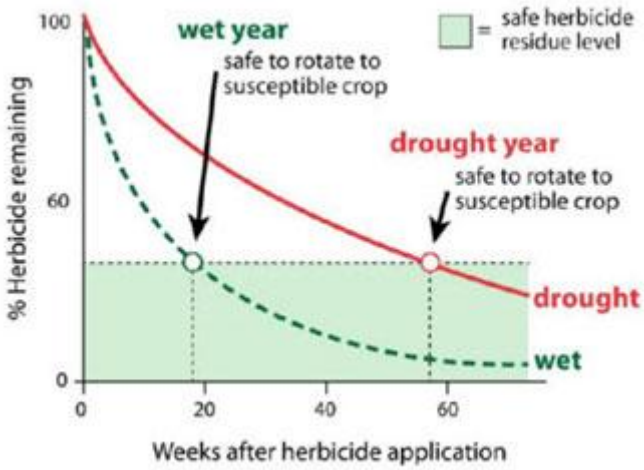


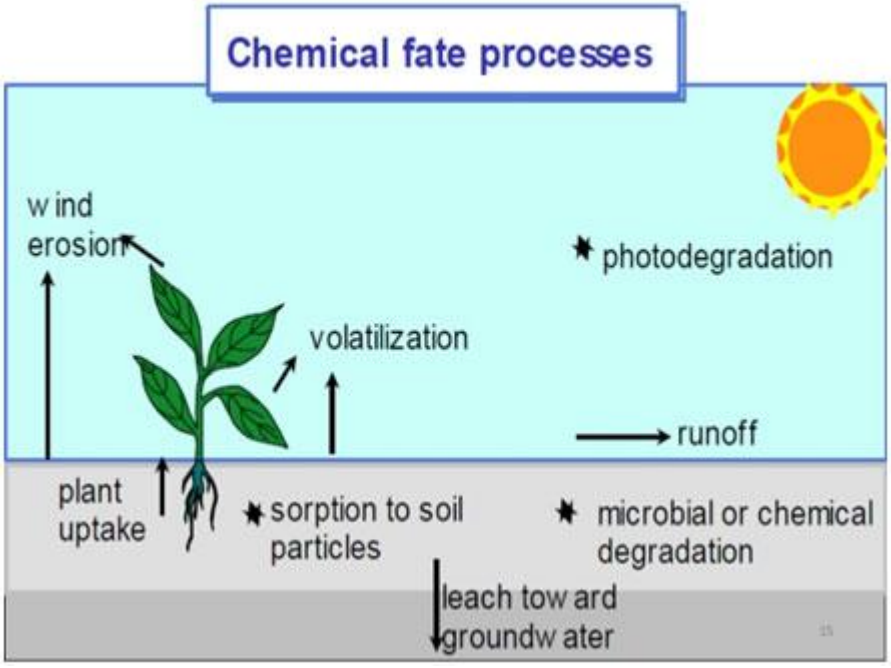
Illustration of effect of soil moisture on herbicide persistence. ***Herbicides can persist much longer in dry soil*** *versus wet soil. (www.striptillfarmer.com)*

Residue is the amount of pesticide that remains in the environment after an application or a spill. A residue is desirable when it provides long-term pest control and reduces the need for repeated applications. However, some persistent pesticides can harm sensitive plants or animals, including humans. Therefore, it is especially important to prevent persistent pesticides from moving offsite through improper handling, application, drift, leaching, or runoff.

Besides being a hazard to persons and non-target animals entering a treated area, the application of persistent pesticides may produce illegal residues on rotational food or feed crops. There are legal limits, called **tolerances**, to protect consumers. **There are limits on the amount of residue that may remain on products sold for food or feed.** Check the label for statements about the persistence of the pesticide and for replanting restrictions. The rate of pesticide breakdown relates to its persistence.

Pesticide Breakdown

Several processes break down pesticide compounds into simpler and often less toxic chemicals. Some pesticides break down very rapidly—in a matter of days or even hours. Others may remain in the environment for a year or more.



Pesticide breakdown processes (slideshare.net)

Pesticides are broken down or degraded by:

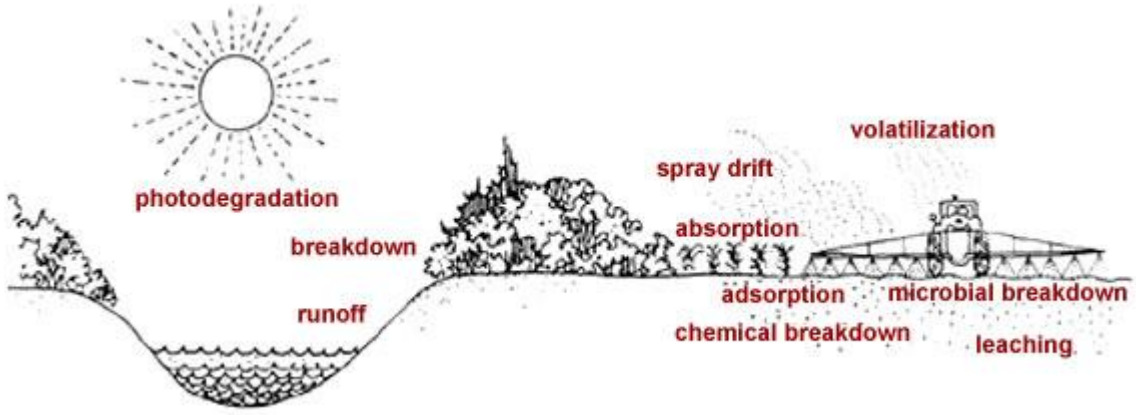
- **Chemical degradation** usually involves a chemical reaction with water; it does not involve living organisms.
- **Microbial action** is the breakdown of chemicals by soil microorganisms, such as fungi or bacteria.
- **Photodegradation** is the breakdown of chemicals in reaction to sunlight.

Water and temperature both affect the breakdown of pesticides. **Warm, wet conditions can increase the speed of pesticide breakdown; cool, dry conditions slow down the degradation process**.

Volatility is the tendency of a pesticide to turn into a gas or vapor. Some are more volatile than others. The chance of volatilization increases as temperatures and wind increase. Also, volatility is more likely under conditions of low relative humidity because evaporation increases in drier conditions.

How Pesticides Move in the Environment

Pesticides may move from the targeted application site in several ways: in air, in water, attached to soil particles, and on or in objects.



Movement in Air

Drift is the movement of a pesticide from the application site by wind or air currents. People who mix, load, and apply pesticides outdoors are usually aware of how easily pesticides may drift offsite. They may travel as spray droplets, vapors, dusts or solid particles, and even on blowing soil particles.

Movement in Water

Most off-site pesticide movement in water is either by **runoff** (surface movement) or by **leaching** (downward movement through the soil).

Runoff and leaching may occur when:

- Too much pesticide is applied or spilled onto a surface.
- Too much rain or irrigation water moves pesticide through the soil offsite or into groundwater.
- Highly water-soluble or persistent pesticides are used.

Runoff water may move pesticides into drainage systems, streams, ponds, or other surface water, where they can travel great distances. Pesticides that leach downward through the soil may reach groundwater. In a greenhouse, pesticides may leach through the soil or other planting medium and contaminate other greenhouse surfaces. Look for special instructions on the label that warn of pesticide hazards caused by the movement of pesticides in water. Sometimes labels require buffers or setbacks from water and wells. *(photo: www.treehugger.com)*

Movement On or In Objects, Plants, or Animals

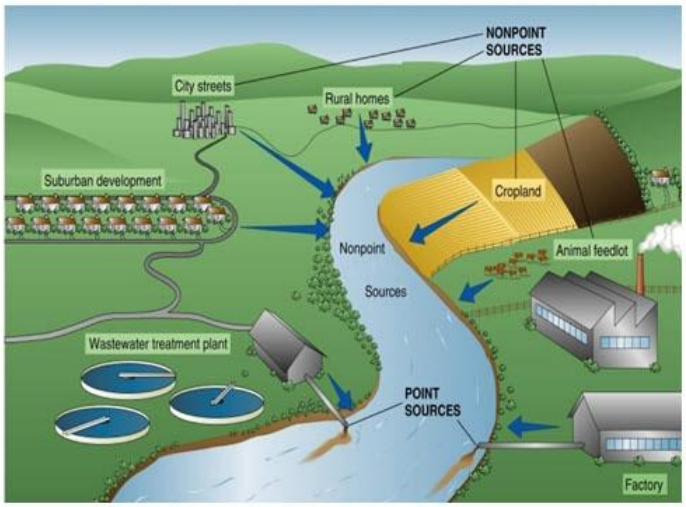
Pesticides also can move from the application site when they are on or in objects or organisms that move offsite. When pesticide handlers bring or wear home contaminated personal protective equipment, work clothing, or other items, pesticide residues may rub off on carpeting, furniture, and laundry items and onto pets and people.

Sources of Water Contamination

Surface water or groundwater contamination results from either point-source or nonpoint-source pollution. Nonpoint-source pollution from pesticide applications is usually blamed for pesticide contamination. However, studies show that water contamination may also result from point-source pollution.

Point-source pollution comes from a specific, identifiable location:

- A pesticide spill entering a storm sewer.
- Back-siphoning of pesticides into water supplies.
- Contaminated surface water entering sinkholes.
- Repeated pesticide spills at mixing and loading sites.
- Careless spilling of wash water at equipment cleanup sites.
- Improper handling of spills and leaks at storage sites.
- Improper disposal of containers, rinsate from containers, and excess pesticides.



Potential point source pollution: Do not leave granular herbicides and pesticides where they can enter storm drains.

Nonpoint-source pollution comes from a widespread area. An example is the movement of pesticides into streams or groundwater after broadcast applications to large agricultural fields, rights-of-way, or turf areas.

Pesticide Contamination of Surface Water

Surface water is often a source of drinking water. Therefore, pesticide contamination of surface water (such as ditches, streams, rivers, ponds, and lakes) is a health concern. Pesticides that move in runoff water or with eroded sediment may contaminate plants and animals located downslope and reach sources of surface water.

Factors affecting runoff and erosion rates include slope, vegetative cover, soil characteristics, volume and rate of water moving downslope, temperature, and rainfall amount and intensity. These factors influence how much water runs off and how much moves into the soil (infiltration). In urban areas, runoff may occur on hard surfaces when pesticide granules are left on sidewalks and streets.

Runoff is a potential problem at most application sites. It is critical that runoff does not carry the pesticide into water sources or other vulnerable areas. Generally, runoff risk is greatest when heavy rains immediately follow pesticide applications or when the ground is saturated or frozen. Although surface waters are most likely to be contaminated by runoff, groundwater may also be affected when surface streams connect with shallow groundwater.

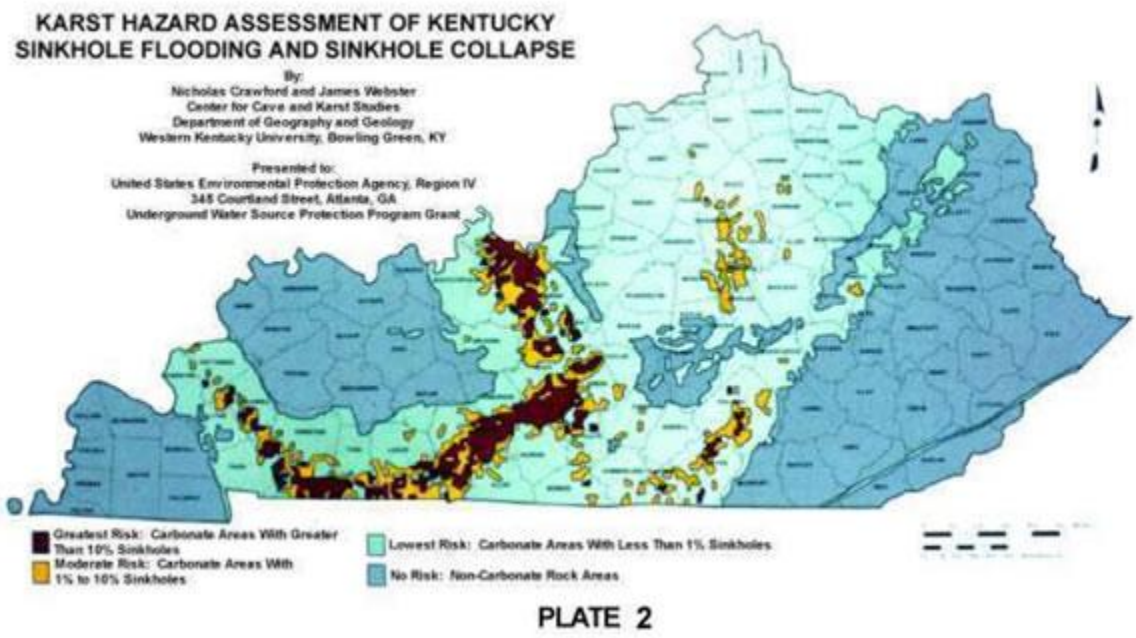
Pesticide Contamination of Groundwater

Nationally, groundwater provides 70% of the water used for public and private water supplies, irrigation, and industry. Like surface water, groundwater must be protected from contamination. **Once groundwater is contaminated, correcting the problem is difficult or even impossible. Groundwater** is found underground in cracks in the bedrock and in the spaces between soil particles, gravel, and rocks. It is the source of water for wells and springs. The layer of soil, sand, gravel, or fractured bedrock in which all available spaces are filled with water is the **saturated zone**. The boundary between the saturated zone and the overlying unsaturated rock and soil is known as the **water table**. The overall geologic formation from which groundwater can be drawn is called an **aquifer**.

Kentucky water statistics

- **Approximately 49 inches of precipitation falls on Kentucky every year. About 40% of this water runs off into streams, 60% evaporates or is transpired by plants.**
- **Kentuckians use more than 4.3 billion gallons of water every day. About 95% of this is from surface water, the rest is from groundwater**
- **More than 1.5 million Kentuckians are served by 185 public water-supply systems that rely on groundwater; 416,000 Kentuckians use water wells or springs**
- **Non-point sources pollute about 3.5 times as many miles of streams as point sources.**
- **Primary nonpoint sources of pollution are: - Mining, 31%- Agriculture, 29% - Land disposal/septic systems, 20% - Urban runoff, 10%**
- **Karst topography refers to areas with sinkholes, springs, caves, and underground streams. Approximately 38% of Kentucky is underlain by limestone exhibiting some karst development, and 25% has well-developed karst features**

Karst is a terrain with distinctive landforms and hydrology created from the dissolution of soluble rocks, principally limestone and dolomite. Karst area (yellow to dark brown on the map below) is characterized by springs, caves, sinkholes, and a unique hydrogeology that results in aquifers that are highly productive but extremely vulnerable to contamination. In the United States, about 40% of the groundwater used for drinking comes from karst aquifers.



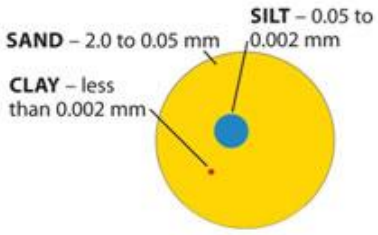
Pesticides can enter groundwater quickly through sinkholes. Follow label directions concerning buffer zones to reduce the chances of contamination.

Some pesticides reach groundwater by moving through the soil in a process called **leaching**. A pesticide that leaches into groundwater must move down through the soil in water and resist binding to soil particles and breaking down into nontoxic compounds. **Pesticides that have high solubility, low adsorption, and/or are persistent are more likely to leach.** They typically have a label statement describing these concerns. A pesticide that adsorbs or binds itself strongly to soil particles will not leach as easily. Besides the characteristics of the pesticide, soil properties and environmental conditions also affect whether and to what extent a pesticide will leach.

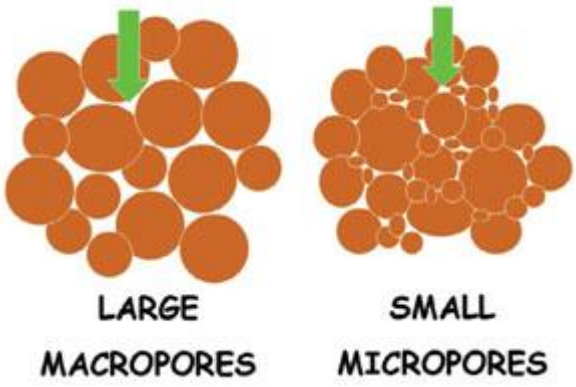
Four soil properties affect a pesticide's potential for leaching:

- texture and structure,
- organic matter,
- depth to groundwater
- geology.

Soil texture is the relative proportions of sand, silt, and clay-sized particles. Percolating water moves faster in sandy soils. Sand also has fewer binding sites available for the adsorption of dissolved chemicals than do clay or silt soils. Though sandy soils are more prone to pesticide movement, leaching may also occur in clay or silt soils. *(Image: soils4teachers.com)*



Soil structure is the shape or arrangement of soil particles. It plays a big role in determining the size and shape of the pores through which water moves. Small amounts of pesticides may also move through soil cracks, worm holes, and root channels. These features are called **macropores**.



Soil pores (sportsfieldmanagementmagazine.com)

Organic matter consists of decaying plant material. The higher the soil organic matter content, the greater the ability of the soil to hold both water and adsorbed pesticides. Pesticides held in the root zone are less likely to leach into groundwater and may be taken up by plants.

Depth to groundwater - **Areas with a shallow water table have a greater chance for groundwater contamination** because less soil is available to act as a filter. There are fewer opportunities for pesticide degradation or adsorption. When using pesticides in areas where the groundwater is close to the surface, choose a product with a low leaching potential. Take extra precautions during mixing, application, and cleanup.

The **permeability of the geologic layers** lying between the surface of the soil and the groundwater is also an important factor. Highly permeable materials (such as gravel deposits) allow water and dissolved pesticides to move freely downward to groundwater. Layers of clay, which are much less permeable, can inhibit and slow the downward movement of water.

Preventing Surface Water and Ground Water Contamination

To help prevent surface water and groundwater contamination, EPA requires all pesticide products labeled for outdoor uses to include the following environmental hazard statement on the label: "***Do not apply directly to water, or to areas where surface water is present, or to intertidal areas below the mean high water mark. Do not contaminate water supplies when cleaning equipment or disposing of equipment wash waters.***"

Pesticides that could contaminate groundwater must bear **groundwater warning statements** on their labels. When such statements appear on product labels, choose pesticides appropriate for use in sandy soils or where extra precautions are needed to reduce the risk of water contamination. You can minimize the risk of point or nonpoint-source contamination by following best management practices (BMPs). BMPs are effective, commonsense procedures that emphasize proper mixing, loading, application, and disposal of pesticides. **Following BMPs reduces the chance that pesticides will harm the environment.**

☑ Use Integrated Pest Management Principles

Apply pesticides only when and where necessary, and only in amounts adequate to control pests. Use nonchemical control methods whenever possible. When using pesticides:

- Determine the type of pest, the density of the pest population, and the proper control method.
- If a pesticide is necessary, choose the least toxic product that will do the job.
- Calibrate pesticide application equipment regularly.
- Use spot treatments or band applications, if possible, to reduce pesticide use.

☑ Identify Vulnerable Areas

The presence of **sandy soil, sinkholes, wells, streams, ponds, and shallow groundwater increases the chance of groundwater contamination**. Never dispose of empty pesticide containers in sinkholes, or dump or rinse sprayers into or near sinkholes. Avoid contaminating drainage ditches and other potential sources of runoff to streams and waterways. Never clean tanks or intentionally discharge water from a tank of any vehicle into a street, along a road, or into a storm drain.

☑ Do Not Mix and Load Near Water

Mix and load as far as possible (at least 50 feet) from wells, lakes, streams, rivers, and storm drains. When possible, do so at the application site. Consider using a sealed permanent or portable mixing and loading pad to prevent seepage into soil.

Photo: duolift.com

☑ Keep Pesticides Away from Wells

Do not store or mix pesticides around wells. Poorly constructed or improperly capped or abandoned wells may allow surface water containing pesticides and other contaminants direct entry into groundwater. Note that wells are sometimes located in or near treated fields and other application sites.

Back-siphoning is the reverse flow of liquids into a fill hose. It sucks tank contents back into the water supply. Back-siphoning starts with a reduction in water pressure and **can draw very large quantities of pesticide directly into the water source**. This happens when the end of the water hose is allowed to extend below the surface of the spray mixture when filling a spray tank.

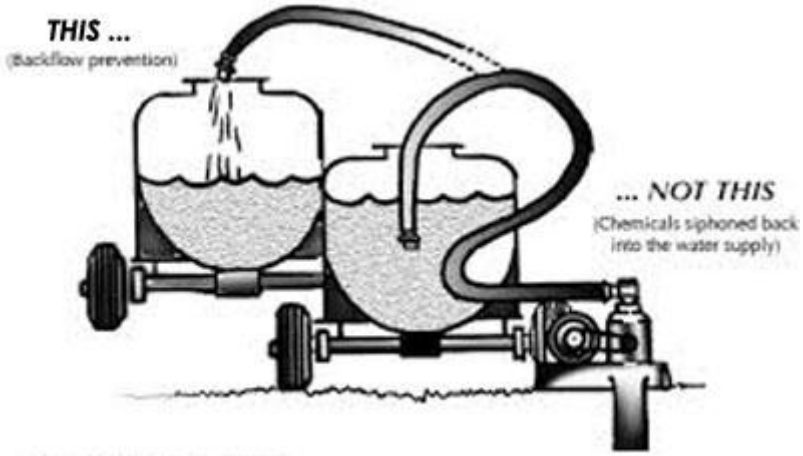


Figure 3: Backflow Prevention
Source: *Protecting Our Groundwater, A Grower's Guide*, USDA Extension Service

The simplest way to prevent backflow is to maintain an air gap between the discharge end of the water supply line and the pesticide solution in the spray tank. An air gap prevents contamination of the hose and keeps pesticides from back-siphoning into the water source if a drop or loss of water pressure occurs. **Keep the air gap at least twice the diameter of the discharge pipe.** Another method to prevent back-siphoning is to use a backflow prevention device or check valve.

☑ Improve Land Use and Application Methods

Terraces and conservation tillage practices can reduce water runoff and soil erosion. Ideally, **growers should leave as much plant residue as possible on the soil surface to lessen erosion.** Where conservation tillage is not possible, decrease runoff potential by incorporating a low concentration of the pesticide into the soil. In ornamental plantings, consider using mulches to reduce water runoff and soil erosion. Grass buffer strips are very effective in reducing pesticide runoff because they trap sediment containing pesticides and slow runoff water. This allows more runoff water to infiltrate the soil. Leaving untreated grass strips next to streams, ponds, and other sensitive areas can trap much of the pesticide running off treated areas.

☑ Time Pesticide Applications According to the Weather Forecast

Pesticides are most susceptible to runoff from heavy rains or irrigation during the first several hours after application. Do not apply to saturated or frozen ground. To avoid over-spraying an area and causing drift, check the pesticide label for application precautions or restrictions during windy conditions. Wind speed, temperature, and humidity all affect the off-target movement of pesticides. *(Photo: indianapublicmedia.com)*

☑ Select Products Wisely

Whenever possible, use pesticides that are less likely to leach. Read labels for such warnings.

☑ Handle Pesticides Safely

Follow these guidelines to prevent surface water or groundwater contamination:

- **Immediately contain and control pesticide spills.**
- **Check application equipment regularly for leaks or damage.**
- **Mix and load pesticides away from water sources.**
- **After the pesticide application is complete, follow label directions for proper equipment cleanup and container disposal.**
- **After applying granular pesticides, sweep or blow any granules from sidewalks, driveways, or patios onto the treatment area.**

Whenever possible, clean sprayers at the application site at a safe distance from wells, ponds, streams, and storm drains. Spray the rinsate on the treated area or on another site listed on the pesticide label, or use in the next tank mix. Be sure not to exceed label rates.

Preventing Harmful Effects on Sensitive Areas and Non-target Organisms

Be aware of sensitive areas, non-target plants and animals (especially endangered species), and damaging effects on habitat. In addition to water sources, sensitive areas include sites where living things could easily be injured by a pesticide.

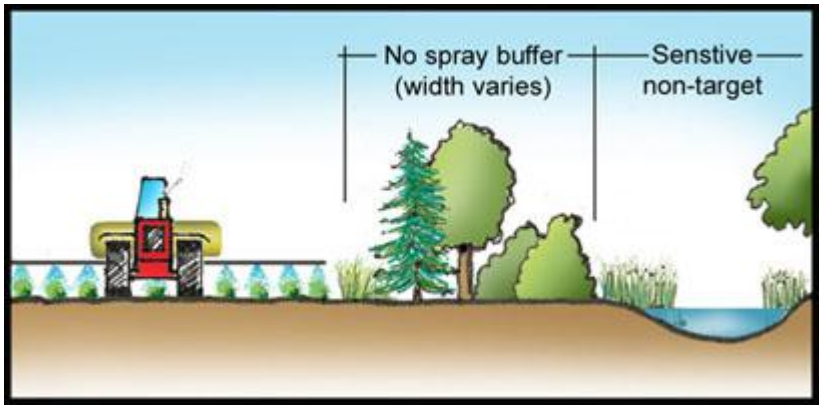
Kentucky bee yard (honeybeesuite.com)

Outdoor sensitive areas include:

- School grounds, playgrounds, and recreational areas.
- Habitats of endangered species.
- Apiaries (honey bee sites), wildlife refuges, and parks.
- Areas where domestic animals and livestock are kept.
- Ornamental plantings, public gardens, and sensitive food or feed crops.
- Indoor areas where ornamental or other sensitive plants are grown or maintained (such as in malls and buildings).

Sometimes pesticides must be deliberately applied to a sensitive area to control a regulated pest (such as mosquito abatement or gypsy moth forest treatments). Only well-trained applicators should perform these applications. At other times, the sensitive area may be part of a larger target site. Whenever possible, take special precautions to avoid treating the sensitive area.

Leaving an untreated buffer zone around a sensitive area is a practical way to avoid contaminating it. In still other instances, the sensitive area may be near a site used for mixing and loading, storage, disposal, or equipment washing. Be very careful to avoid contaminating the sensitive area. Check the label for statements that alert you to special restrictions around sensitive areas. *(Image: nac.unl.edu)*



Pesticide Effects on Non-target Organisms

Pesticides may affect non-target organisms directly, causing **immediate injury**. Or they may produce **long-term consequences** through environmental pollution. Pesticides may build up in the bodies of animals or in the soil. For example, if you use the same mixing and loading site or equipment cleaning site over a long period, pesticides are likely to accumulate in the soil. When this occurs, plants and animals that come into contact with the soil may be harmed.

Non-target Plants

Nearly all pesticides can cause plant injury (**phytotoxicity**) due to chemical exposure, particularly if applied at too high a rate, at the wrong time, or under unfavorable environmental conditions. Phytotoxicity can occur on any part of a plant—roots, stems, leaves, flowers, or fruits.

Growth regulator type injury (ncsupdicblog.blogspot.com) (left) and Glyphosate injury (ncsupdicblog.blogspot.com)(right)

Some symptoms of phytotoxicity:

- Death of seedlings
- Death of rapidly growing succulent tissues
- Stunting or delayed plant development
- Misshaped or distorted plants, fruits, or leaves. Dead spots or flecks on leaves.
- Dead leaf tips or leaf margins.
- Dead areas between the veins of the leaves

Although damage to crops or other nearby plants is primarily caused by drift, it may sometimes be a consequence of surface runoff and root uptake.

Bees and Other Beneficial Insects

Besides making honey and beeswax, bees pollinate many fruit, nut, seed, vegetable, and field crops. You must be aware of bee activity when planning pesticide applications. There has been increasing concern about the decline of bee colonies and the role pesticides may play. Preventing bee loss is the joint responsibility of the applicator, the grower, and the beekeeper.

Honey bees may travel as far as 3 miles from their hive to find blooming flowers. Before applying pesticides labeled as toxic to bees, notify beekeepers in the area so they can protect or move their bee colonies. *(Photo: flicker.com)*

Bees and other insect pollinators may be exposed to pesticides through different routes, including:

1. **Direct contact** during foliar applications.
2. Contact with **residues** on plant surfaces after applications.
3. **Drift** from the application into the hive entrance.
4. **Ingestion of residues** in nectar, pollen, or guttation water (dew) when the pesticide is applied as a seed treatment, soil or tree injection, or foliar application.

Insecticides are generally toxic to bees, but some are more hazardous than others. Herbicides are unlikely to harm bees directly. Fungicides do not appear to affect adult bees but may affect larval development. Tank mixing insecticides and fungicides may create a mixture that is more toxic to bees than either product used alone.

Minimize bee kills from insecticide poisoning by following a few basic principles:

- **Pay careful attention to pesticide labels. For each application site, look for the bee hazard icon in the "Directions for Use" section for specific use restrictions and instructions to protect bees and other pollinators.**
- **Do not apply insecticides to crops in bloom.**
- **Apply insecticides in the evening or at night when bees are not foraging. (Early morning application may protect honey bees, but wild bees forage at or before dawn.)**
- **Do not apply insecticides when weeds or other plants around the treatment site are in bloom.**
- **Do not allow the pesticide to drift onto attractive habitat, natural areas, or beehives.**
- **Choose the least hazardous insecticide, formulation, and application method.**

Pollinator protective warning label (goodnewsnetwork.com)

Pesticides can harm other beneficial insects in addition to bees. These beneficials may be valuable allies in keeping pest populations below damaging levels. **A pesticide application often harms the beneficial insect population as much or more than the target pest. So do not spray when beneficial insects are in the target area unless it is unavoidable. Alternatively, choose a product that does not harm beneficials.**

Fish, Wildlife, and Livestock

Pesticides can harm all kinds of animals. **Most injuries occur from the direct effects of acute poisoning.** Fish kills often result from water pollution by a pesticide. Insecticides are the most likely cause, especially when small ponds or streams are under conditions of low water flow or volume.

Bird kills resulting from pesticide exposure may happen in a number of ways. Birds may: ingest pesticide granules, baits, or treated seeds; be exposed directly to sprays; consume treated crops or drink contaminated water; or feed on pesticide-contaminated insects and other prey. Granular or pelleted formulations are a particular concern because birds and other animals often mistake them for food. **Liquid formulations may be safer when birds and other wildlife are in or near the treated area.** Remove pet dishes from spray areas. Place baits properly so they are inaccessible to pets, birds, and other wildlife.

Animals may also be harmed when they eat plants or animals carrying pesticide residues. Predatory birds or mammals feeding on animals killed by pesticides are a special concern. Pesticide residues remaining on or in the bodies of the dead animal may harm predators. This is called secondary poisoning. Check the pesticide label for statements about secondary poisoning.

The less obvious effects resulting from long-term exposure to pesticides are a major concern. For example, certain pesticides have been banned because of fish and bird kills and the reproductive failures of several bird species.

The **most important source of livestock pesticide poisoning has been through contaminated feed, forage, and drinking water.** Contamination often occurs as a result of improper or careless transportation, storage, handling, application, or disposal of pesticides.

Protecting Endangered Species

Certain plants and animals have been identified as endangered or threatened species. Be very careful not to harm these populations. Because all living things are part of a complex, delicately balanced network, removing a single species may set off a chain reaction that affects many other species. The full significance of extinction is not always readily apparent, and the long-term effects are often difficult to predict.

An **endangered species** is one on the brink of extinction throughout all or a significant part of its range. A **threatened species** is one likely to become endangered. The reasons for a species' decline are usually complex, and thus recovery is difficult. A major problem for most wildlife is the destruction of habitat, usually the result of industrial, agricultural, residential, or recreational development. Here is a list of threatened and endangered species in Kentucky.

Each state is responsible for implementing the federal **Endangered Species Protection Program** in cooperation with EPA to protect endangered and threatened species from the harmful effects of pesticides. Under this program, pesticide products that might harm an endangered species carry a label statement instructing applicators to consult a county bulletin to determine if they must take any special precautionary measures when using the product. EPA develops these bulletins, which identify precautionary measures required in each county where one or more pesticides could affect an endangered or threatened species. **Precautionary measures may include buffer strips, reduced application rates, and timing restrictions. Or an applicator might be prohibited from using the pesticide within the identified habitat altogether.** Check with your state, tribe, or territory department of agriculture; local Extension Service; or the EPA website to find out the status of available county bulletins.

Summary

An important part of using pesticides legally and responsibly is considering where the pesticide may end up once it leaves the container and whether it might harm or damage non-target sites, plants, or animals. By applying pesticides at the right time, in the right place, and with the proper application technique, you can greatly reduce—or even prevent—drift, runoff, and leaching.

Pesticides that enter groundwater and surface water are hazardous to aquatic organisms, plants, and wildlife. Therefore, you should implement best management practices to prevent runoff and leaching of pesticides. Sensitive areas include places such as schools, playgrounds, endangered species' habitats, and ornamental plantings. Non-target organisms include plants, bees and other beneficial insects, fish, wildlife, and livestock.

Because of the greater risk of injury to people, plants, and animals, you must know when and how to properly apply pesticides in or near such areas. Always check the label for statements on endangered and threatened species. You may need to consult a county bulletin that details the procedures for protecting them. **It is your responsibility not only to follow label directions but also to use the best management practices that present the least risk to the environment while achieving effective pest control.**