General Knowledge: Pesticide Use and the Environment

Pesticide Use and the Environment Learning Objectives

After studying this section, you should be able to:

- ✓ **Describe the chemical characteristics that control pesticide movement in the environment.**
- ✓ **Describe the different ways pesticides can move in the environment.**
- ✓ **Describe the different types of pesticide drift and the factors that can affect pesticide drift.**
- ✓ **Explain why it is important to protect water resources, especially groundwater resources, from pesticide pollution.**
- ✓ **List the different methods pesticide applicators can use to reduce or prevent surface water and groundwater contamination.**
- ✓ **Explain potential pesticide effects on non-target organisms and methods to reduce or prevent these potential effects.**
- ✓ **Describe the Endangered Species Act and how it applies to pesticide applications.**

Pesticide Use and the Environment

After a pesticide is applied, whether to a plant, an animal, the soil, inside a structure, out-of-doors or to any other site, it has been introduced into the environment. Applicators need to ask themselves a few important questions:

1. Will the pesticide remain where it was applied or will the pesticide become mobile in the environment?
2. How long will the pesticide remain viable or effective?
3. What effect could the pesticide have on non-target plants, animals, or other things in the environment?

Once applied, all pesticides are considered to have been introduced into the environment.

Four basic chemical characteristics control pesticide movement:

Solubility is the ability of a pesticide to dissolve in a solvent, usually water.

Adsorption is the ability of a pesticide to bind with soil particles.

Persistence is the ability of a pesticide to remain in its original active form and not break down into an inactive form.

Volatility is the ability of a pesticide to turn into a gas or vapor.

To answer these questions, you must understand how pesticides move in the environment and the chemical properties that control movement. There are four basic chemical characteristics that control pesticide movement in the environment: solubility, adsorption, persistence and volatility.

Solubility is a measure of the ability of a pesticide to dissolve in a solvent, usually water. The greater the solubility, the more readily the pesticide dissolves. Pesticides that are easily dissolved in water can move with water. Highly soluble pesticides are more likely to move through the soil and into groundwater or into surface waters, causing harm to unintended sites, plants and animals, including humans.

Adsorption is the ability of a pesticide to bind with soil particles. Adsorption occurs because the pesticide has an electrical attraction to the surface electrical charge of a soil particle, generally organic matter or clay particles. A pesticide that adsorbs to soil particles is less likely to move from the application site.

Persistence is the ability of a pesticide to remain in its original form, active and viable, before breaking down chemically to become inactive. A common measure of persistence in chemicals is referred to as the half-life. Half-life is the time it takes for half the original amount of chemical applied to break down. The longer the reported half-life of a chemical or pesticide, the more persistent the chemical or pesticide is in the environment. Sometimes, persistent pesticides are desirable because they will provide long-term pest control and reduce the need for repeated applications. However, persistent pesticides can also cause later problems to unintended sites, plants, animals or humans if the persistent pesticides are also mobile in the environment. If you are using a persistent pesticide, it is very important to prevent unintended consequences due to improper handling, drift, runoff, erosion or leaching.

Volatility is a measure of the tendency of a pesticide to turn into a gas or vapor. Some pesticides are more volatile than others. Pesticides tend to volatilize more readily when temperatures are high, winds are high, and relative humidity is low at the application site. Pesticide movement as a gas or vapor is also known as “drift” and will be discussed in the next section.

Pesticide degradation occurs in three basic ways:

- Microbial action: chemical breakdown or degradation of pesticides by soil microorganisms, such as fungi, bacteria, etc.
- Chemical degradation: Breakdown of pesticide chemical components by inorganic methods (not by living organisms).

- Photodegradation: breakdown of pesticide chemical components by reaction with sunlight. This is why many pesticide application instructions require incorporation of the pesticide in the soil, away from direct sunlight.

How do Pesticides Move in the Environment?

It would be ideal if pesticides always remained on the target site, whether single plants, farm fields, road sides, soil, or structures. However, pesticides are capable of moving in the environment and under certain conditions they do not always remain on the target site. Pesticides can move in the air, in water, and through the soil resulting in environmental damage and exposure to nontarget plants and animals. Applicators are responsible for damages resulting from off-target pesticide movement.

Pesticide Drift

Pesticide drift is the movement of pesticides through the air away from the intended target site. When pesticide drift occurs, it can damage crops and expose humans, domestic animals and wildlife. Drift can contaminate soil and water.

Pesticide movement in water usually is the result of either **runoff** from the application site to an unintended site or water body or **leaching** from the soil by water, moving outward and/or downward in the soil. This can cause unintended harm to plants or animals or contaminate surface water or groundwater.

Movement on or in objects includes such things as:

- Pesticide **residues** on equipment or clothing used by pesticide applicators. These residues can affect unintended plants, wildlife, livestock, pets and people.
- Pesticides that have adsorbed on soil particles that are subsequently moved to an unintended site by wind or water **erosion**.
- Pesticide **residues** on plants that are removed from site. This may be as plant parts, feed, seed or other plant-based products.
- Pesticide **residues** on or in animals that are treated by pesticides and moved to a new site. The residues can be in the meat, milk or fiber used by man, on their fur or skin, in their feces or other waste products, etc.

Minimizing pesticide movement and subsequent unintended application and damage is part of the pesticide applicator's job.

Pesticide degradation occurs in three basic ways:

- **Microbial action**
- **Chemical degradation**
- **Photo-degradation**

Drift is the movement of pesticides through the air to non-target sites.

Pesticide residues are the product's active ingredient(s) or its breakdown product(s) that remain in the environment after application.

Minimizing pesticide movement and subsequent unintended application and damage is part of the pesticide applicator's job.

There are two types of drift: vapor drift (chemical volatility) and particle drift.

Vapor drift is the movement of pesticide vapors from the target area, carried by air.

Particle drift is the movement of small spray droplets or dust from the target area, carried by air.

Temperature influences the volatility of pesticides.

The size of the spray droplets determines how fast the droplets fall and how far the pesticide might drift. Small, lightweight droplets fall more slowly and have more time to drift.

Types of Pesticide Drift

There are two types of pesticide drift: particle drift and vapor drift. Drift may occur outdoors during agricultural and pesticide applications or indoors, moving on air currents through ventilation systems.

Vapor drift occurs when pesticide surface residues change from solids or liquids to gases or vapors after the application of a pesticide has occurred. This process is called volatilization. Once airborne, volatile pesticides can move long distances from the site of application. Fumigant pesticides used to treat soil before planting and to treat structures such as homes or storage bins are especially volatile.

Not all pesticides are volatile. The potential for volatilization increases as the temperature increases. At higher temperatures, more product will be converted to the volatile form. Pesticide labeling describes precautions to take in order to avoid damage from volatile pesticides.

Particle drift is made up of small pesticide spray droplets or dust carried by air movement from the target area during application.

Factors Affecting Drift

Many factors influence the amount of particle spray drift. Of primary concern are **spray droplet size** and **wind velocity,** as they are the cause of most of the problems associated with spray drift. Droplet size produced by the sprayer, droplet velocity, and direction of the wind all impact spray drift.

The size of the spray droplets dictates how fast they fall to the ground and how far they drift. Small, lightweight droplets fall very slowly and consequently drift farther away from the target site. The diameter of spray droplets is measured in microns. A micron is 1/1000 of a millimeter (the diameter of a human hair is approximately 50 microns). Droplets that are smaller than 50 microns are highly susceptible to drift under normal conditions. The ideal range of spray droplet diameters for general ground spray application is 80 to 150 microns. The fall rate and lateral drift of different spray droplets is summarized in the table on the next page.

As droplet size increases, the potential for drift decreases. Because of this, it is desirable to operate a sprayer so that it produces the largest droplets that will provide adequate coverage of the target area. However, as droplet size increases, the volume of water required to give the same degree of coverage also increases. Most farmers apply pesticides in less than 25 gallons of water per acre in order to minimize the quantity of water that needs to be hauled to the field.

Influence of droplet size on potential distance of drift

Type of Droplet	Diameter (in microns)	Time required for droplets to fall 10 ft.	Lateral distance traveled by droplets[1]
Fog	5	66 minutes	3 miles
Very fine spray	20	2 minutes	1,110 feet
Fine spray	100	10 seconds	44 feet
Medium spray	240	6 seconds	28 feet
Coarse spray	400	2 seconds	8.5 feet
Fine rain	1,000	1 second	4.7 feet

[1] Droplet falling 10 feet in a 3 mph wind

In order to achieve adequate coverage of the target area with these volumes, especially with post-emergence chemicals, it is necessary to equip the sprayer with nozzles that produce fairly small droplet sizes. This is why there is always a potential for drift, and why it is critical to pay attention to the factors that influence the amount of off-target pesticide movement.

Wind velocity or speed is another factor affecting drift. The greater the wind speed, the greater the drift. Below five miles per hour (mph), wind poses very little drift hazard. Nearly all the spray particles will have a chance to deposit on the ground, or in or on the plant canopy. When wind speed increases above 5 mph, the potential for drift increases. Winds over 10 mph will control and carry all of the small particles and will affect the drift of medium and large particles.

In general, wind speed is reduced just before sunrise and just after sunset. Air is usually the most turbulent during mid-afternoon. Also take into account the direction of the wind before applying pesticides. Do not apply pesticides when the wind is blowing toward an adjoining susceptible crop, water body, sensitive site, etc.

Several other minor factors influence the potential for drift. These factors should be considered when operating under conditions favorable for drift.

- Physical properties of liquids: The viscosity of a liquid is a measure of its resistance to flow. For example, mayonnaise is more viscous than water. As the viscosity of a liquid increases, the droplet size of the spray increases. The addition of thickening agents to the spray increases the number of large droplets and reduces drift. Drift control agents include foam additives, invert emulsions and thickeners. Research with ground sprayers indicated that the addition of a spray thickener reduced spray drift by 66 to 90 percent. However, some post-emergence herbicides require small droplets for optimum performance, so techniques that

As droplet size increases, the potential for drift decreases.

The greater the wind speed during a pesticide application, the greater the risk of pesticide drift.

Consider wind direction when planning a pesticide application. Do not apply pesticides when the wind is blowing towards a susceptible crop, water body or other sensitive site.

Winds are generally calmer in early morning or early evening. These are better times of day to apply pesticides.

Low relative humidity and/or high temperature increase the evaporation rate of spray droplets.

Spray drift is usually greater from aerial applications than from ground applications.

increase droplet size may reduce weed control. Always follow the label directions regarding the use of any spray additives.

- Air stability: Air turbulence is influenced by the temperature at ground level and the temperature of the air above it. When the air near the soil surface is warmer than the air above it, the warm air rises and the cool air settles, resulting in a gentle mixing of the air. This condition occurs early in the morning and in the early evening. These are the best times to apply pesticides since any pesticide released into the atmosphere will disperse slowly.

  As the temperature near the soil increases, the hot air rises faster and mixes rapidly with the cooler air above it, causing windy conditions. These windy conditions occur during mid-day, and the wind velocity can exceed 10 mph.

  Temperature inversion occurs when there is cool air near the surface, under a layer of warm air. Temperature inversions often occur early in the morning. A temperature inversion allows very little vertical mixing of air, even with wind. Damage from spray drift is most severe during temperature inversions since small spray droplets or vapors will be suspended in the cool air layer at crop height for long periods of time.

- Humidity and temperature: Low relative humidity and/or high temperature increase the evaporation rate of water spray droplets. Evaporation reduces droplet size, and in turn, increases the potential for droplet drift. Droplets greater than 150 microns are not significantly affected by evaporation.

- Method of application: Spray drift is usually greater from aerial applications than from ground applications. Low-pressure ground sprayers usually produce larger spray droplets that are released closer to the target than aerial sprays. Irregular air movements around the fixed wing of airplanes or the rotary blades of helicopters also increase the potential for spray drift.

  Keep booms mounted as low as possible to diminish wind effects but allow the recommended spray overlap between nozzles. Do not adjust the boom lower than the recommended height for the nozzle type you are using. Flat fan tips are available in several nozzle angles. Using a wide-angle tip allows the boom to be placed closer to the ground, reducing the potential for drift.

- Spray nozzles: Pesticide spray nozzles are an integral part of pesticide application equipment. Good uniformity of the application depends on proper nozzle selection. Nozzles help control the amount of pesticide applied and the size of the droplets. Droplet size depends on both the nozzle and the pressure. Droplet size decreases with high pressure and increases with low pressure. The bigger the droplet, the less likely it is to drift.

Nozzles may be constructed of a variety of materials, including stainless steel, nylon, aluminum, brass or ceramic. Some materials are very durable, such as stainless steel. Nozzles made from brass wear out quickly, especially when using wettable powders.

Some basic nozzle types include:

- Fan or flat fan nozzles: These nozzles are used for herbicide and insecticide applications. They put out the spray in a fan-shaped pattern with less material applied at the edge of the pattern, so the spray pattern must overlap in order to obtain uniform coverage.
- Hollow cone nozzles: These nozzles produce a cone-shaped spray pattern, with the liquid on the outside of the cone. Hollow cone nozzles generally produce the smallest droplets and are used when penetration and coverage are critical.
- Full cone nozzles: This type of nozzle produces a cone-shaped spray pattern with liquid being applied throughout the cone. They are often used for soil-applied herbicides.

- Spray pressure: Spray pressure influences the size of droplets formed from the spray nozzle. Increasing nozzle pressure will increase the number of small droplets that are susceptible to drift. It is important to use pressures within the guidelines of the particular nozzle type. Operating outside of the suggested range may distort the pattern, resulting in non-uniform coverage, often increasing drift.

Proper nozzle selection helps maintain uniform application by controlling both the amount of pesticide applied and the size of the pesticide droplets.

Spray pressure influences the size of the droplets formed. Increased pressure produces smaller droplets, which are more susceptible to drift.

Water Resources

The water cycle or hydrologic cycle is one of the oldest recycling systems on earth. No new water is ever created. Instead, the water cycles through a complex system fueled by the sun that continually replenishes water supplies. The hydrologic cycle moves water among Earth's land, atmosphere and oceans.

The major processes moving the water are evaporation, transpiration, condensation and precipitation. **Evaporation** occurs when the sun's energy turns liquid water on the Earth's surface into water vapor, which enters the atmosphere. Water vapor leaves plants in a process called **transpiration**. Collectively, these two processes are referred to as **evapotranspiration**.

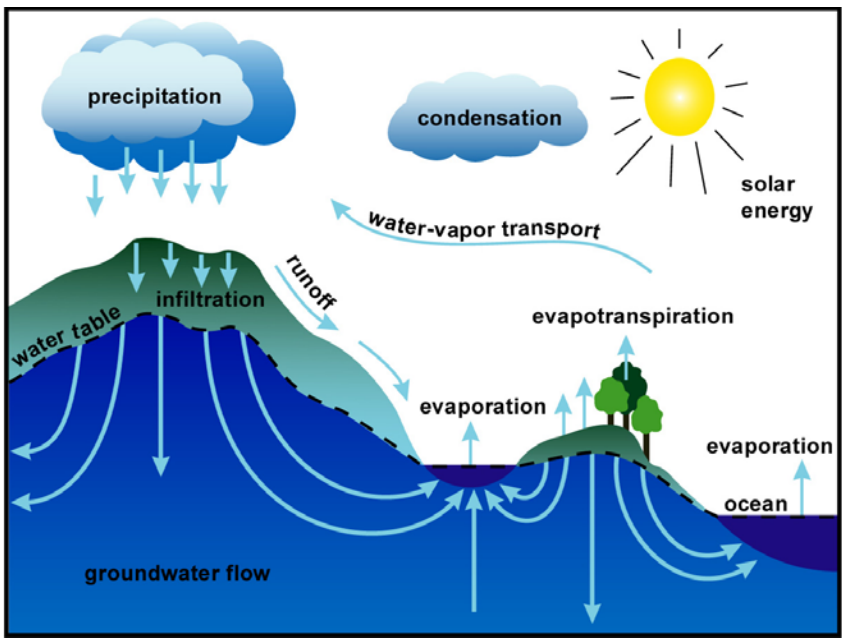
An aquifer is a geologic formation from which groundwater can be drawn. It can be a layer of sand, gravel or other soil materials, or a section of bedrock with fractures through which water can flow.

Groundwater is widely used for household and irrigation water supplies.

When the water vapor in the atmosphere cools and forms clouds, it is called **condensation**. When the water in the atmosphere falls back to Earth as rain or snow, it is called **precipitation**. Rainfall and snowmelt contribute to the surface water in streams, rivers, lakes, ponds, etc.

Precipitation also soaks into the ground or infiltrates, replenishing the water in the soil. Some of this water continues to infiltrate below the soil. This subsurface water accumulates within cracks in bedrock or fills the spaces between particles of soil and rocks. The groundwater layer in which all available spaces are filled with water is called the saturated zone. The dividing line between the saturated zone and overlying unsaturated rock or sediments is called the water table.

The geologic formation through which groundwater flows is called an aquifer. This can be a layer of sand, gravel, or other soils, or a section of bedrock with fractures through which water can flow. Groundwater is the source of water for wells and springs, which are the source of drinking water for many communities.



The Water Cycle

Groundwater: Water entering the soil gradually percolates downward or laterally to become groundwater. This hydrologic process is referred to as **recharge**. Groundwater does not consist of large underground lakes or streams. Rather, it is water that moves slowly through irregular spaces within rock fractures or between particles of sand, gravel or clay. Groundwater may eventually discharge (exit) through springs or seeps into surface water bodies such as streams or lakes.

Groundwater is usually very clean because it is filtered as it squeezes through porous spaces in the rock. When groundwater becomes contaminated, fixing the problem is difficult and is prohibitively expensive. The degradation of pesticides in groundwater is extremely slow because of the low temperatures, low microbial activity, and absence of light.

Surface Water: Surface water resources include water in oceans, rivers, lakes, streams and ditches. Surface water is linked to groundwater by recharge through water bodies such as streams and lakes. Most agricultural and urban areas drain into surface water systems, making surface water especially vulnerable to pesticide contamination. When pesticides enter surface water, they can be transported downstream and spread throughout rivers, streams, lakes and oceans.

Pesticide Contamination and Water Resources

Pesticides can contaminate surface water and groundwater from both point sources and non-point sources. Point sources are from specific locations such as spill sites, disposal sites, pesticide drift during applications, and application of pesticides to control aquatic pests. Nonpoint sources are currently the major contributors to surface water and groundwater contamination and may include agricultural and urban runoff, erosion, leaching from application sites, and precipitation that has become contaminated by upwind applications. Pesticides typically enter surface water when rainfall or irrigation exceeds the infiltration capacity of soil, or the soils ability to absorb the water. Resulting runoff then transports pesticides to streams, rivers and other surface-water bodies.

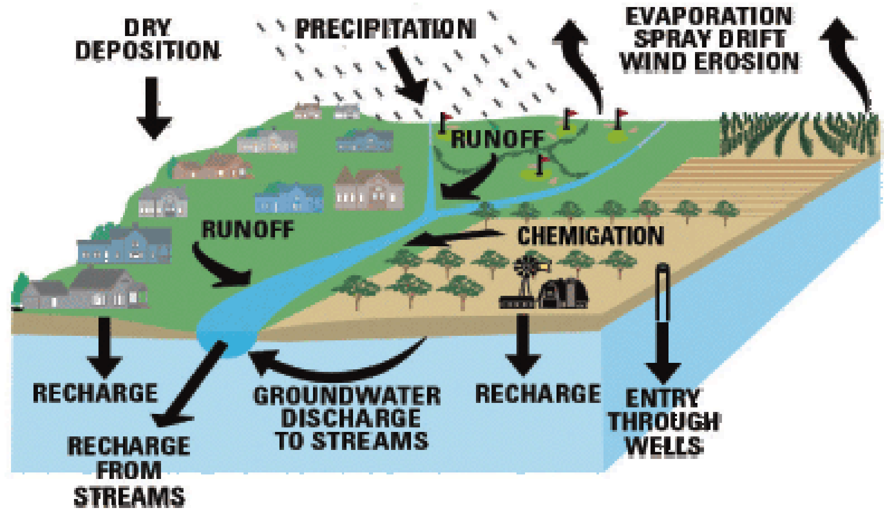
Pesticides also enter surface waters through drift. Contamination of groundwater may result directly from spills near poorly sealed wellheads and from pesticide applications made using improperly designed or malfunctioning irrigation systems. Groundwater contamination also may occur indirectly by the percolation of agricultural and urban irrigation water through soil layers into groundwater and from pesticide residues in surface water, such as drainage ditches, streams and municipal wastewater.

The diagram below illustrates routes of pesticide introduction into streams and groundwater. (Modified from Gilliom and others, 2006.)

Once groundwater is contaminated, it is difficult and expensive to decontaminate.

Pesticides can contaminate surface water and groundwater from both point sources and nonpoint sources.

Chemicals on the ground surface can become groundwater contaminants if they are carried downward by recharge water.



Leaching is the term for transport of pesticides downward or sideways through soil.

The risk of groundwater contamination is greater when pesticides are applied to gravelly or sandy soils.

The closer the water table is to the land surface, the greater the possibility of contamination.

Runoff and erosion moves pesticides into surface water bodies, such as streams or lakes.

Leaching is the term for the transport of pesticides downward or sideways through soil. Some pesticides move readily through soils that are well-drained, sandy or low in organic matter. Sandy soils have low water-holding capacity, support smaller populations of microorganisms that can break down pesticides, and lack clay and organic matter to bind the chemicals. Because of these factors, the risk of groundwater contamination is greater when pesticides are applied to gravelly or sandy soils than to other soil type.

The potential for pesticide movement in the soil varies according to the nature of the pesticide, the properties of the soil, the application practices used, irrigation and precipitation. The closer the water table is to the land surface, the greater the possibility of contamination. Pesticide labeling describes environmental hazards and may include groundwater advisory statements. These are instructions that may prohibit the product's use in areas where groundwater is vulnerable to pesticide contamination. As an example, some product labels will advise users not to apply the pesticide to sand or loamy sand soils in areas where the water table is close to the surface.

Runoff is the process of water moving across the soil surface or other hard surfaces when it arrives faster than it can soak into the soil. Runoff is usually produced by rain, melting snow, or irrigation water. Some pesticides eventually end up on soil or on paved surfaces. As water runs off and the soil erodes, the pesticides are carried along with the water and soil particles. Runoff and the erosion it causes move pesticides downhill into streams, rivers, ponds and lakes.

Runoff can occur from all types of sites, including agricultural areas, rangeland, compacted soils and roadside rights-of-way. Pesticides applied in urban areas to structures, and landscapes can be a significant source of surface water contamination. According to U.S. EPA, because of impervious surfaces such as rooftops and pavement, a city block produces nine times more runoff than a wooded area of the same size. When urban runoff enters storm drains it can carry pesticide pollutants with it directly to streams and rivers.

Protecting Water Resources

Preventing water contamination by pesticides is the responsibility of every pesticide applicator. Follow these pesticide application guidelines

Follow the direction on the pesticide label. The pesticide label is designed to provide the applicator with useful and important information in order to use the pesticide efficiently, safely, and legally. There are four times when the pesticide label should be read: (1) before a pesticide is purchased, (2) before the pesticide is mixed and applied, (3) before the pesticide is stored, and (4) before disposing of the pesticide container.

Pesticide labels contain the following information: the brand name, common name, type of formulation, ingredient statement, net contents, name and address of manufacturer, EPA registration and establishment number, statement of use classification (general or restricted-use), signal words (danger, poison, warning, caution) and symbols (skull and cross bones), precautionary statement, statement of first aid, directions for use, misuse statement, re-entry information, storage and disposal directions, residues, and restrictive statement. Pesticide labels contain information on protecting water resources and preventing contamination.

There are both civil and criminal penalties for using a pesticide in a manner that conflicts with the label. Always practice the following:

- **Measure pesticides carefully.** Pesticides should always be used at the rate specified on the label. Always read the label before you begin to mix the pesticide to make sure you have a measuring device that will accurately measure the correct amount of pesticide required. Measure pesticides carefully, accurately, and safely.
- **Direct pesticide applications to the target site.** Avoid overspraying the ground to prevent the possible introduction of the pesticide into water. Applications that are effectively directed to the target will reduce drift and are less likely to contaminate water sources.
- **Dispose of pesticides properly.** After the pesticide application is complete, the applicator should take care in disposing of the excess pesticide and the pesticide container. Follow the label for proper

Preventing groundwater contamination is the pesticide applicator's responsibility.

Always read, understand and follow directions and precautions on the product label.

Use pesticides only when and where necessary and only in amounts adequate to control pests.

There are both civil and criminal penalties for using pesticides in a manner inconsistent with label directions.

Read, understand and follow the information and instructions on the pesticide labelregarding disposing of

pesticides and storing pesticides safely.

Maintain records of pesticide applications, as required.

Additional groundwater protection methods, such as timing of irrigation, avoiding irrigation runoff and regularly inspecting and maintaining water wells, can help prevent groundwater contamination.

pesticide disposal to avoid groundwater contamination. Triple-rinsed or pressure-rinsed pesticide containers to prepare them for disposal. Pour the rinse water back into the spray tank and use it to treat the site or crop. The best precaution against pesticide disposal problems is good planning. This begins with buying and mixing the right amount of pesticide.

- **Store pesticides safely.** The law requires that pesticides be stored in a safe, secure, and well-identified place. Pesticides must always be stored in the original, labeled container with the label clearly visible. Store pesticides in a cool, well-ventilated, secured (locked) location away from wells, pumps, or other water sources. Seal pesticide containers tightly and periodically check them for leakage, corrosion breaks, tears, etc.
- **Maintain records of pesticides that were used.** Information from these records may help to prevent future contamination of the groundwater and help protect the applicator should questions about treatments arise in the future. Private applicators must keep records of pesticide applications and maintain them for possible inspections for two years.
- **Use additional water protection methods,** such as carefully timing irrigation, avoiding runoff, and inspecting wells, to prevent groundwater contamination by pesticides.
    - **Time irrigation:** If it is practical, delay irrigation for one or more days after a pesticide application. A delay in irrigation gives the plants and the soil more time to take up the pesticide. This reduces the amount of pesticide that is available for movement through the soil with irrigation. This reduces the chances of the pesticide reaching the groundwater.
    - **Avoid irrigation runoff.** This reduces soil erosion and decreases the chances of the pesticide entering surface water and groundwater. Extra care should be taken when irrigating and applying pesticides on clay soils because they are especially susceptible to runoff.
    - **Inspect wells to prevent groundwater contamination.** A well acts as a direct pipeline to groundwater. Groundwater can become contaminated if pesticides or other pollutants enter a well directly from the surface, through openings in or beneath a pump base, or through soil adjacent to the well. Proper well construction can prevent groundwater contamination. Locate wells away from pollution sources likely to contaminate the well. Proper seals between the pump and the pump base help prevent the entry of contaminants. Seals between the casing of the well and the wall of the hole can prevent water near the soil surface from entering the well and possibly contaminating the groundwater. In Nevada, a well

must be sealed from the ground surface to a depth of at least 50 feet with neat cement.

Proper maintenance of existing wells helps prevent groundwater contamination. Inspect wells and pumps regularly for leaks and to ensure the seal is adequate to prevent pesticides from entering the groundwater. Check irrigation pipes for leaks that could lead to contamination of the groundwater.

Chemigation

Chemigation is the application of agricultural chemicals through an irrigation system. Particular care should be used when practicing chemigation. The irrigation may carry the pesticides downward through the soil to groundwater. Devices must be used to prevent possible back siphoning of the pesticides into the water supply system.

Chemigation has the advantage that the correct amount of chemical can be applied to the crop at the appropriate time, the application is inexpensive, convenient, and field access is unnecessary.

Apply chemicals only through the type of irrigation systems listed on the product label. Chemigation systems must include the following:

- The system must contain a functional check valve, vacuum relief valve, and low-pressure drain appropriately located on the irrigation pipeline to prevent water source contamination from backflow.
- The chemical injection pipeline must contain a functional, automatic, quick-closing check valve to prevent the flow of fluid back toward the injection pump.
- The chemical injection pipeline must contain a functional, normally closed, solenoid-operated valve located on the intake side of the injection pump and connected to the system interlock to prevent fluid from being withdrawn from the supply tank when the irrigation system is either automatically or manually shut down.
- The system must also contain functional interlocking controls to automatically shut off the chemical injection pump when the water pump motor stops.
- The irrigation line or water pump must include a functional pressure switch that will stop the water pump motor when the water pressure decreases to the point where chemical distribution is adversely affected.
- Systems must use metering pumps, such as a positive displacement injection pumps (e.g., diaphragm pumps) effectively designed and

Chemigation is the application of agricultural chemicals, both pesticides and fertilizers, through a sprinkler system.

For further information on Chemigation, see Category 14, Chemigation in this manual.

Phytotoxicity: poisonous toplans, a chemical that causes damage or death to plants.

Be aware of bee activity when applying pesticides.

Before applying pesticides that are toxic to bees, notify beekeepers in the area.

Use insecticides that are relatively non-hazardous to bees whenever possible.

Apply pesticides in the evening or early morning, when bees are not actively foraging.

constructed of materials that are compatible with pesticides and capable of being fitted with a system interlock. Crop injury, lack of effectiveness, or illegal chemical residues in the crop can result from non-uniform distribution of treated water.

See "Calibration of Chemigation Equipment" under the "Guidelines for the Safe Use of Pesticides" section for information on calibrating chemigation equipment. See Category 14, Chemigation for further information.

Pesticide Effects on Non-Target Organisms

The effects of pesticides on non-target organisms may involve direct and immediate injury or may be due to the long-term consequences of environmental pollution. Valuable non-target plants, bees and other beneficial insects, pets, livestock, and wildlife may be affected.

Pesticide effects on non-target plants

Nearly all pesticides can cause plant injury, particularly if they are applied at too high a rate, at the wrong time, or under unfavorable environmental conditions. **Phytotoxicity** refers to plant injury caused by exposure to a chemical. Phytotoxic injury can occur on any part of a plant's roots, stems, leaves, flowers or fruits.

Most phytotoxic injuries are due to herbicides that are persistent at the site of application. Persistent products may also injure succeeding crops.

Damage to crops or other plants in adjacent areas is most often due to drift, although damage may sometimes be a consequence of surface runoff, particularly from sloping areas.

Pesticide effects on bees

Bees pollinate many fruit, vegetable and field crops. Always monitor for bee activity prior to applying pesticides. Prevention of bee harm or loss is the joint responsibility of the applicator, the farmer and the beekeeper. Before applying pesticides that are toxic to bees, notify commercial beekeepers in the area so that they can protect or move their bee colonies. In addition, take the following steps to protect bees:

- Read the label and follow label recommendations.
- Apply chemicals in the evening or during early morning hours before bees forage. Evening applications are generally safer than morning applications. If unusually warm evening temperatures cause bees to forage later than usual, delay the pesticide application.
- Do not spray crops in bloom except when absolutely necessary.

- Do not treat an entire field or area if local spot treatments will control the pest.
- Use insecticides or other pesticides that are relatively nonhazardous to bees, whenever possible.
- Choose the least hazardous pesticide formulations. Emulsifiable concentrates are safer than wettable powders, and granules are the safest and least likely to harm bees.
- Determine if bees are foraging in the target area so that protective measures can be taken.
- Be aware that airplane applications are more hazardous to bees than ground applications.

Pesticide effects on beneficial insects

Beneficial insects other than bees can also be harmed by pesticides. Despite the fact that they are valuable allies in keeping pest populations below damaging levels, we often overlook them in our pest control efforts. When we apply pesticides, we frequently succeed in reducing beneficial insect numbers as effectively as those of the pests themselves. This allows the resurgence of the pest population to be faster and greater because the beneficial predators have been eliminated or are slower to rebound.

Pesticide effects on pets

Keep pets out of treated areas during applications and cover pet food and water bowls. After walking through treated areas, pets may lick their paws and become exposed to the chemical, so it is advisable to keep pets out of the treated areas until the pesticide has completely dried.

Apply rodenticide baits in bait stations and insect baits in locations where pets can't get to them. Information about bait stations and bait placement can be found on the pesticide labels.

Some pesticides are manufactured specifically for use on pets. Read, understand and follow label directions carefully. It is especially important to use these types of products only for the species of animals they are actually labeled for. For example, do not use products labeled for dogs on cats.

Pesticide effects on livestock

Livestock poisoning by pesticides occurs as a result of contaminated feed or forage and contaminated drinking water. This is often due to carelessness, and may result from improper transport, storage, handling, application or disposal of pesticides.

Applying a pesticide to a forage crop that is not listed on the label and then feeding the forage to livestock may result in illness or death of the animals.

Beneficial insects, other than bees, can also be harmed by pesticides. Survey the insect population and use caution when applying pesticides.

Keep pets out of treated areas during applications and cover pet food and water bowls.

Applying a pesticide to a forage crop that is not listed on the label and then feeding the forage to livestock may result in illness or death of the animals.

Pesticides can affect wildlife in many ways. They may kill wildlife, weaken wildlife, kill their food source or interfere with reproduction.

Lethal effects are those that cause death directly by exposure to pesticides.

Sublethal effects are those that do not kill outright, but those that interfere with survival and reproduction.

Some pesticide labels list grazing restrictions, which are periods of time that livestock must be excluded from the treated area after treatment. Grazing restrictions prevent adverse effects to livestock and livestock products from occurring as a result of pesticides used on pasture and range sites.

Pesticide effects on wildlife

Adverse effects of pesticides on wildlife can differ widely. For example, rodenticides applied in a manner that is not consistent with label instructions can kill non-target species, such as birds and mammals. Some pesticides, especially insecticides, are very toxic to fish and other aquatic life. When these products drift or run off into waterways, aquatic species may suffer adverse effects. Insecticides kill important insects that are a vital part of the food chain. Herbicide use can eliminate habitat that is valuable for insects, birds and mammals.

Insecticides and rodenticides are sometimes intentionally misused to kill nuisance wildlife. **This is a violation of pesticide labeling**. It is also a serious violation of state and federal wildlife laws and regulations.

Insecticides and rodenticides are generally more toxic than herbicides to wildlife. Few acute or chronic effects on wildlife are currently known to be connected with herbicide use.

Wildlife can be exposed to a chemical by eating contaminated food, by drinking contaminated water, by breathing the chemical, by absorbing the chemical through the skin, or by swallowing the chemical while grooming. Young birds can die from insecticides by eating or being fed insects that have been contaminated. These are called **lethal effects**.

Insecticides also can damage the central nervous system of wildlife in such a way that the animal does not die, but shows abnormal behavior affecting its ability to survive or reproduce. These are called **sublethal effects**.

Insecticides also can affect wildlife indirectly by killing insects other than crop pests. Insects are very high in protein, which is necessary for growing birds. The growth of young birds, such as ducklings, is stunted in areas where insecticides are heavily used because they do not have enough insects to eat.

Fish also feed on insects, as well as very tiny water animals called zooplankton. Scientists say that fish also may show stunted growth in areas with heavy insecticide use because both the aquatic insects and the zooplankton are killed. This, in turn, affects fish reproduction because the number of eggs a fish can produce is directly related to its size and health.

Some persistent pesticides are of particular concern because they can accumulate in the bodies of animals in the fat tissue. This process is referred to as **bioaccumulation or bioconcentration**. Many of the chlorinated hydrocarbons (DDT, heptachlor, chlordane) are both persistent and accumulative. These properties account for most of the environmental problems associated with their use. As a result, EPA has canceled the use of most chlorinated hydrocarbons.

Accumulative pesticides can build up in the food chain. A **food chain** describes the sequence whereby an animal feeds on a particular plant, animal, or microorganism and is in turn eaten by another animal and so forth until we reach the animal at the top of the chain. At each succeeding level, an animal normally eats a number of individuals from a “lower level.” For example, birds might eat insects, and then larger birds might eat smaller ones. An accumulative pesticide can, therefore, become increasingly concentrated as it moves up the food chain. This process is referred to as **biomagnification**. For example, in a study where levels of DDT in the soil were 10 parts per million (ppm), it reached a concentration of 141 ppm in earthworms and 444 ppm in robins.

Application hazards

Any application method or farming practice that allows considerable drift or runoff is potentially harmful to wildlife. Insecticides aerially applied near wetlands can contaminate these areas. In 1987, an aerial application of ethyl parathion, an organophosphate insecticide, to sunflower fields adjacent to wetlands in North Dakota led to the death of 96 percent of the mallard ducklings in the wetlands. When the pilot was instructed to avoid these areas, no deaths occurred.

Granular insecticides and rodenticides are attractive to birds. Some birds can die from swallowing even a single granule of some of these products.

By following the best management practices outlined in this study guide, you can minimize pesticide impacts on wildlife. If you apply pesticides near wetland or other wildlife habitat, consider the following strategies:

- Avoid contaminating wetland areas when aerially spraying. Instruct applicators to avoid spraying wetlands or other natural areas.
- Use buffer zones of unsprayed crops or grass strips to protect wetlands or other natural areas.
- Plant and protect grass Conservation Reserve Program (CRP) filter strips at least 66 to 99 feet around wetland areas.
- When applying pesticides, try to choose chemicals that are not as hazardous to wildlife. Near ponds and streams, avoid using pyrethroids where they may run off into the water. Pyrethroids are a good

Bioaccumulation or bioconcentration is the accumulation of persistent pesticides in the bodies of animals.

Biomagnification is the accumulation of persistent pesticides in increasing concentration in animals as it moves up the food chain.

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For additional Endangered Species information:

Nevada Natural Heritage Program, Department of Conservation and Natural Resources
901 South Stewart Street, Suite 5002
Carson City, NV 89701-5245
Phone: 775-684-2900
Fax: 775-684-2909
http://heritage.nv.gov

Nevada Department of Agriculture
405 South 21st Street
Sparks, NV 89431
Phone: 775-353-3600
http://www.agri.state.nv.us

University of Nevada Cooperative Extension
4955 Energy Way
Reno, NV 89502
Phone: 775-784-4848
Fax: 775-784-4881
http://www.unce.unr.edu

U.S. Environmental Protection Agency Pesticides: Endangered Species Protection Program,
http://epa.gov/espp/

alternative in upland areas because they have low toxicity in birds and mammals.

- Avoid draining wetlands for planting and avoid cultivating and using pesticides on wetland borders and wetlands that are dry in drought years. Wetlands that are cultivated in dry years may be wet again the next year. Some chemicals may remain in the soil and may be harmful to both wildlife and habitat.
- Use the RAATS (Reduced Agent and Area Treatments) program for applying insecticides to rangelands. The rate of insecticides applied is reduced by alternating untreated swaths with treated swaths.

Protecting Endangered Species

The Endangered Species Preservation Act was passed by Congress in 1966 and amended to the Endangered Species Act (ESA) in 1982. The U.S. Fish and Wildlife Service and the National Marine Fisheries Service are the designated federal agencies that are responsible for administering the law.

The ultimate goal of the ESA is to maintain the natural diversity of plants and animals and the ecosystems upon which they depend. As of 2010, the U.S. Fish and Wildlife Service endangered species list contained more than 1,060 species of plants and animals. An additional 317 species of plants and animals are listed as threatened. Of these, 40 species of plants and animals are federally listed as endangered or threatened in Nevada.

Once listed as endangered or threatened, a species has full legal protection under the Endangered Species Act. All Federal agencies are required to undertake programs for the conservation of endangered and threatened species. They are prohibited from authorizing, funding, or carrying out any action that would jeopardize a listed species or destroy or modify its “critical habitat:” the limited area where an endangered species lives.

The ESA program is concerned about the impact pesticide use limitations or restrictions have on the people who use pesticides. To minimize these impacts, the EPA emphasizes lower pesticide application rates rather than complete prohibition of use in areas where endangered or threatened species and their habitats could be affected by pesticides. The use of lower rates reduces the exposure of endangered and threatened species to potentially harmful pesticides.

The program requires some pesticide manufacturers to place a generic statement on the label. This statement instructs the pesticide’s users to determine if any use limitations exist by visiting the U.S. Environmental Protection Agency’s Endangered Species “Bulletins Live” website, http://epa.gov/espp/. If use limitations are listed, the user is required to understand the information and adhere to its restrictions. The bulletins contain habitat location maps, which pinpoint species habitat locations. The maps can help pesticide users determine if a pesticide application has the potential to impact a threatened or endangered species. The EPA is working with U.S. Fish and Wildlife Service, U.S. Department of Agriculture, the Natural Heritage Program and state agencies to ensure the accuracy of the maps. Contact the Environmental Protection Agency's Endangered Species Hotline, 1-800-447-3813, to find out which counties nationwide are currently included in the program.

Because EPA's Endangered Species Protection Program is constantly changing, check regularly with the Nevada Department of Agriculture for changes in pesticide use restrictions and to learn which bulletins are available. **Remember, if you use pesticides, you are responsible for knowing if an endangered or threatened species or their habitat may be affected by pesticide use in your area.** Read each pesticide label carefully, get the additional information you need, and then observe any necessary limitations that apply to endangered species or their habitats. When you fulfill your responsibilities as a pesticide applicator, you help ensure that the benefits of pesticide use outweigh the risks.

The Nevada Natural Heritage website, http://heritage.nv.gov, lists all the endangered and threatened species in Nevada. Check the website regularly for updates. Endangered and threatened species are also protected in Nevada by the Nevada Revised Statutes (NRS) 501 Fauna (animals), NRS 527 Flora (plants) and the Cactus and Yucca Law (with the exception of the Warner sucker in Washoe County, which is not listed by the state of Nevada).

U.S. Fish & Wildlife Service, Endangered Species Program, http://www.fws.gov/endangered/

Remember, if you use pesticides, you are responsible for knowing if an endangered or threatened species or their habitat may be affected by pesticide use in your area.

Conclusion

Use care when applying pesticides. Read, understand and follow label directions. Read the entire label. Do your best to limit pesticide drift. Be aware that pesticides may adversely affect non-target plants and animals. Pesticides may also contaminate surface and ground waters if not applied correctly. Use pesticides carefully and thoughtfully.

Parts of the water resources section were adapted from:

Thodal, C.E., 2009, Monitoring for pesticides in groundwater and surface water in Nevada 2008: U.S. Geological Survey Fact Sheet 2009-3093, 4 p.

Originally published in 1987 as Pesticide Use and the Environment, Nevada Pesticide Applicator's Certification Workbook, SP-87-07, by W. Johnson, J. Knight, C. Moses, J. Carpenter, and R. Wilson. Updated in 2012 by M. Hefner and S. Donaldson, University of Nevada Cooperative Extension, and J. Carpenter, Nevada Department of Agriculture.

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