Best Management Practices

COLORADO STATE UNIVERSITY
EXTENSION

Agricultural Pesticide Use

Bulletin XCM-177

Best Management Practices for Agricultural Pesticide Use

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Introduction

Pesticides are widely used to protect crops and livestock from losses due to insects, weeds, and diseases. Colorado uses about 1% of the 900 million pounds of conventional pesticide applied annually in the United States. The Environmental Protection Agency (EPA) has estimated that 76% of the total pesticide use nationally is for agricultural production, with the remaining 24% used in the urban, industrial, forest, and public sectors. These chemicals have helped to increase agricultural production and reduce labor costs. However, problems associated with improper pesticide use have led to human illness, injury to non-target species, and water quality degradation.

The major groups of pesticides include insecticides, herbicides, and fungicides. Because herbicides are the most widely used class of agricultural and urban use pesticides, they are the pesticides most frequently found in ground and surface water. The ability to detect pesticides in the environment has greatly improved in recent years. The development of extremely sensitive detection methods has led to the discovery that commonly used management practices may lead to small amounts of pesticides that contaminate ground and surface water supplies. Since we depend on these water supplies for drinking water, pesticide applicators need to exercise a high level of care and use sound pesticide management to avoid contamination.

This guide addresses Best Management Practices (BMPs) for preventing nonpoint source contamination of water resources by agricultural pesticides. Contamination from normal pesticide application is called nonpoint contamination, since a single point of contamination cannot be identified. Point source contamination would include spills of concentrated chemicals at storage, mixing, or loading sites. These point source problems are addressed in the document BMPs for Pesticide and Fertilizer Storage and Handling (Bulletin #XCM- 178).

Since pesticides are an important tool for most farming operations, and cleaning up contaminated groundwater is extremely difficult, producers need to evaluate their use of pesticides and adopt BMPs that are appropriate for their crops and site. Fortunately, a number of crop management and pesticide application practices can be used to reduce potential contamination of water supplies.

Government Regulations and Policy

The federal government has enacted several laws to control pollution of water resources. Among these are the Safe Drinking Water Act; the Clean Water Act; the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA); and the Food Quality Protection Act (FQPA). All pesticides are regulated through FIFRA, and producers should understand that the chemical label is, in effect, the law. In most cases, the precautions on the chemical label are adequate to protect water resources from contamination above a regulatory standard. However, it is possible for a pesticide to reach ground or surface water resources even when used according to the label instructions. Chemicals that have a higher potential to move to groundwater are identified on the label by a "Groundwater Advisory Statement." This statement is usually located in the Environmental

<u>Example Groundwater Advisory Label</u>

Environmental Hazards:

The active ingredient in this product can be persistent for several months or longer and has properties similar to chemicals which are known to leach through soil to ground water under certain conditions as a result of agricultural use. Use of this chemical in areas where soils are permeable, particularly where the water table is shallow, may result in ground water contamination.

This pesticide is toxic to freshwater, estuarine and marine fish and aquatic invertebrates.

Do not apply directly to water except as specified on this label. For terrestrial uses, do not apply directly to water, or to areas where surface water is present or to intertidal areas below the mean high water mark. Drift and runoff may be hazardous to aquatic organisms in neighboring areas. Do not contaminate water when disposing of equipment washwater or rinsate.

Hazards section on the label. Producers should take special care when using these chemicals on sites with conditions that are susceptible to leaching (Table 1) or runoff.

Rather than impose overly restrictive measures on farmers and related industries, Colorado has elected to encourage the voluntary adoption of BMPs that suit the agricultural chemical user's specific managerial constraints while still meeting environmental quality goals. Voluntary adoption of these measures by agricultural chemical users will help maintain the quality of water resources, improve public perception of the industry, and perhaps reduce the need for further regulation and mandatory controls.

Groundwater Monitoring

In 1990, the Colorado legislature passed Senate Bill C.R.S. 25-8-205.5(1), which introduced Colorado's Agricultural Chemicals and Groundwater Protection Act.

This Act declares that the public policy of Colorado is to protect state waters and the environment from impairment or degradation caused by improper use of agricultural chemicals, while allowing for their correct use. The Act also requires the Colorado Department of Agriculture (CDA) to conduct a statewide groundwater monitoring program and aquifer vulnerability analyses. Since 1992, the CDA has been working in cooperation with the Colorado Department of Public Health and Environment (CDPHE) and Colorado State University Extension to implement the Agricultural Water Quality Program (AWQP).

The Program acquires water samples from monitoring, irrigation, and domestic wells throughout the state. These samples are analyzed for a suite of over 100 active ingredients from pesticides registered in Colorado. All well samples are also analyzed for nitrate - nitrogen. In 2019 the Colorado General Assembly passed SB19-186 to expand the groundwater program to cover all State Waters

Trade name	Common name
Weed B Gone	2,4-D, dimethylamine salt
Lasso	Alachlor
Aatrex	Atrazine
Quadris	Azoxystrobin
Hyvar	Bromacil
Furadan	Carbofuran
Dacthal	DCPA
Casoron	Dichlobenil
Imidacloprid 4F	Imidacloprid
Mecoprop dimethylamine salt	MCPP, DMA salt
Dual	Metolachlor
Sencor	Metribuzin
Solicam	Norflurazon
Vydate C-LV	Oxamyl
Tordon	Picloram, potassium salt
Princep	Simazine
Tebufenozide	Tebufenozide
Sinbar	Terbacil
Platinum	Thiamethoxam
Bayleton 50	Triadimefon

Table 1. Commonly used pesticides with groundwater or surface water label advisory statements

including surface water. Surface water monitoring will begin in 2020 and will be incorporated into all of the program's work.

Pesticide and nitrate analysis results from the groundwater monitoring program are available on the Agricultural Water Quality Program database, https://www.colorado.gov/pacific/agconservation/AWQP

The database can quickly and easily be queried based on any number of criteria, including county, region, conservancy district, well use, water quality parameters (i.e., nitrate, pesticide), and year. It also includes a statewide summary of sampling results. The web site features an interactive map of Colorado that displays statewide sampling results for tested water quality parameters.

Pesticide analysis results for monitoring indicate that the highest numbers of wells with pesticide detections are located in the South Platte River Basin. A total of 225 wells have been monitored in the South Platte River Basin, of which 56% are located in Weld County. Of the 125 wells in Weld County, 94% have tested positive for pesticides in the monitoring timeframe. Other areas of the state with a significant number of pesticide detections included the Front Range, Arkansas Valley, and San Luis Valley, with 20%, 11%, and 11% of wells, respectively. The most frequently detected pesticides were atrazine and its breakdown products, prometon and metolachlor. The map in Figure 1 shows the general location of all wells sampled in the state from 1992 to 2018 by the AWQP. The EPA has established primary drinking water standards or health advisory levels for a number of pesticides. Primary drinking water standards are referred to as maximum contaminant levels (MCLs) and represent the highest amount of a contaminant allowed in public water systems. Only six of the wells that tested positive for a pesticide exceeded an established human health drinking water standard.

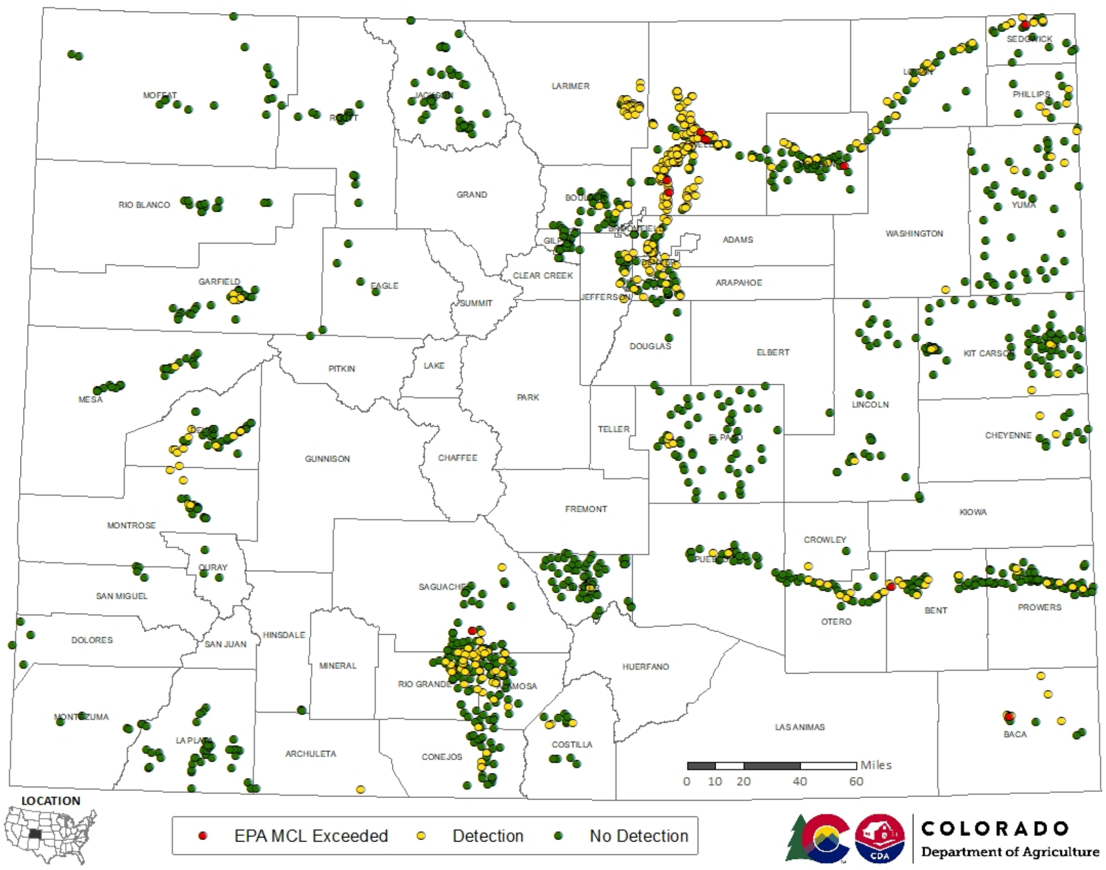

Figure 1. Distribution of locations sampled for groundwater quality by the Colorado Department of Agriculture's AWQP from 1995 - 2018 where no pesticides have ever been detected (green symbol), at least one pesticide compound has been detected in one or more years (yellow symbol), or a concentration was above an established U.S. EPA maximum contaminant level (MCL) for drinking water in one or more years. Source: AWQP Database, https://erams.com/co_groundwater/

These results seem to be promising, given the small number of pesticide detections that exceeded an established health standard or advisory level. However, the existence of any amount of pesticide in Colorado State waters may be an indication of future problems. Continuation of water monitoring by the AWQP will help to identify present and future problem areas of the state so that stakeholders can focus their educational and management activities in regions where it is most needed.

Pesticide Fate in the Environment

Pesticides meet a variety of fates after application. They may evaporate, be broken down by sunlight, or be carried away to surface water before reaching their targets. After reaching the soil, they may be taken up by plants, adsorbed to soil particles, broken down by soil microorganisms, or, in some cases, be transported offsite to water resources (Figure 2). The fate of pesticides in the environment depends upon a number of factors, including: site characteristics, pesticide properties, pesticide use practices.

Typically, the majority of applied pesticides are degraded by soil microbes. However, some pesticides and pesticide breakdown products may reach ground or surface water if the appropriate BMPs are not implemented. Applicators should always evaluate their pest problems and the characteristics of their site to select the most effective control measure with the least potential for environmental impact. Biological controls and treatment cost effectiveness pertaining to economic thresholds should be examined. Some pesticide treatments may not be environmentally or economically wise to perform. See page 10 on Integrated Pest Management (IPM).

Pesticide Properties

Chemical properties of a pesticide cannot be changed by applicators, but they should be considered in order to select the most appropriate product when chemical control is necessary.

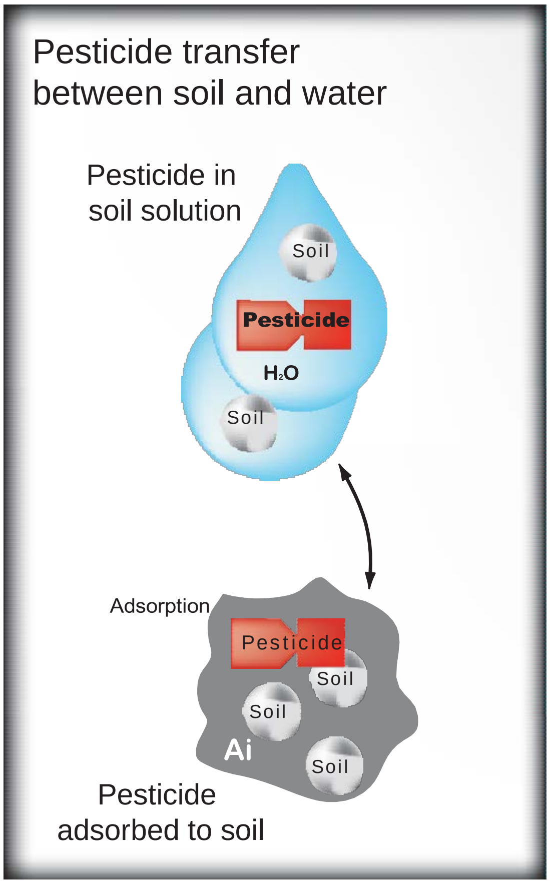

Figure 2. Pesticides will exist in the soil water solution, in soil air, or adsorbed onto soil particles.

The major pathways of pesticide degradation are microbial breakdown, photolysis (breakdown by sunlight), and hydrolysis (breakdown by water). These pathways are influenced by the chemical structure of the pesticide compound, as well as by soil temperature, pH, moisture, and microbial populations. Soil microbes, including bacteria, fungi, and actinomycetes, are the major degradation pathway for most pesticides. Because microbes tend to be most active in the upper portions of the root zone, once a pesticide moves below this level it may be stable long enough to reach groundwater.

Adsorptivity is a measure of how strongly a pesticide is attracted to the negative charges on soil particles. Strongly adsorbed pesticides are less likely to leach, especially on soils with high organic matter or high clay content

(Figure 2). However, they may be more prone to end up in surface water if soil erosion occurs because of wind or water. Adsorptivity is usually expressed as the Kd or K_{OC} of the compound. The higher the number, the more strongly adsorbed the pesticide will be.

Solubility, usually expressed in parts per million (ppm), describes the tendency of a pesticide to dissolve in water. While solubility may influence the amount of a chemical carried in macropore flow, it is generally not as significant as the adsorptivity of a chemical in predicting chemical movement through soil. See the Glossary for additional term definitions.

Volatility is the rate at which a chemical evaporates when in contact with air. Volatile pesticides can vaporize and move by vapor drift. Pesticides can injure non-target organisms and impact surface waters when they vaporize and move off-target.

Pesticide properties only indicate the probability of leaching or runoff; soil, site, and management factors must also be considered. Even if pesticide properties indicate very little environmental risk, they may still end up in water supplies if other factors favor movement. However, in most cases good management will keep water contamination to a minimum.

As shown in Figure 3, groundwater sensitivity to pesticide contamination varies greatly across Colorado due to depth to water table, permeability of materials overlying aquifers, and availability of recharge for transport of contaminants (irrigation). The mapped areas are predominately agricultural, where the bulk of pesticides are used in an irrigated setting. Pesticide applicators should exercise extreme caution when mixing and/or applying pesticides in these sensitive areas, particularly when

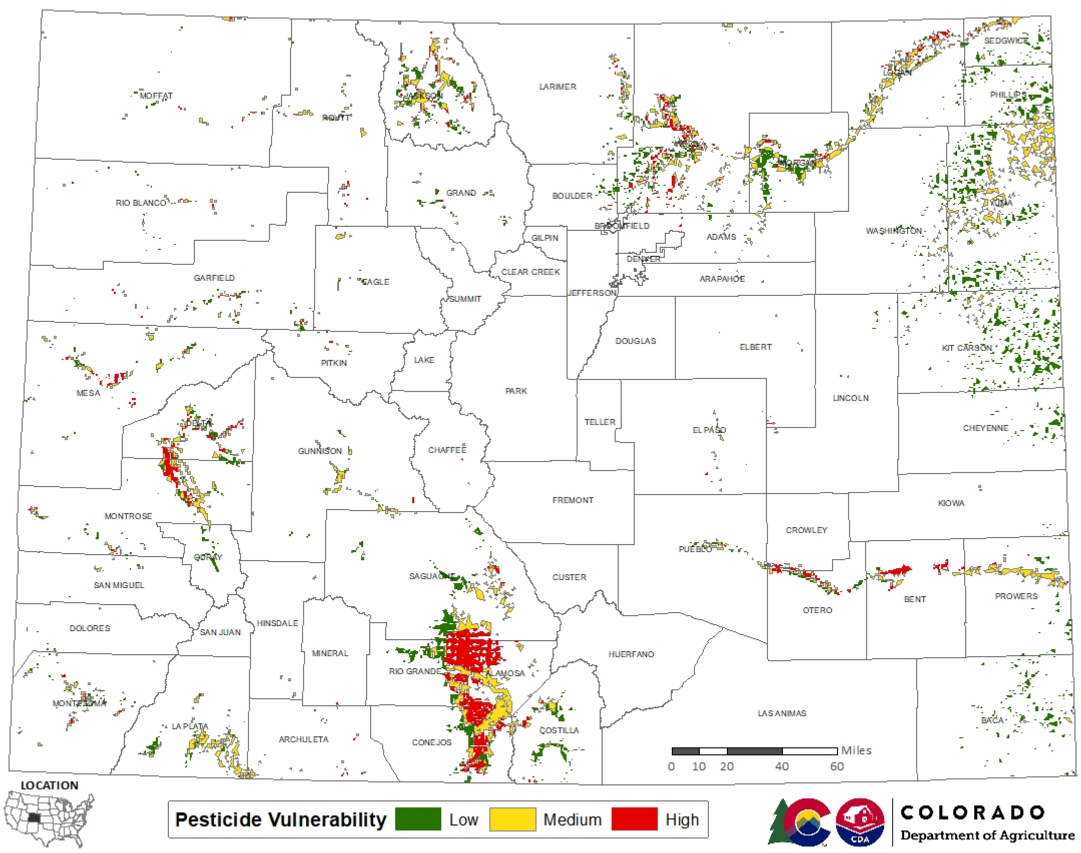

Figure 3. Aquifer areas showing low, medium, or high sensitivity to contamination by pesticides based on the physical setting. Source: AWQP Database: : https://erams.com/co_groundwater/

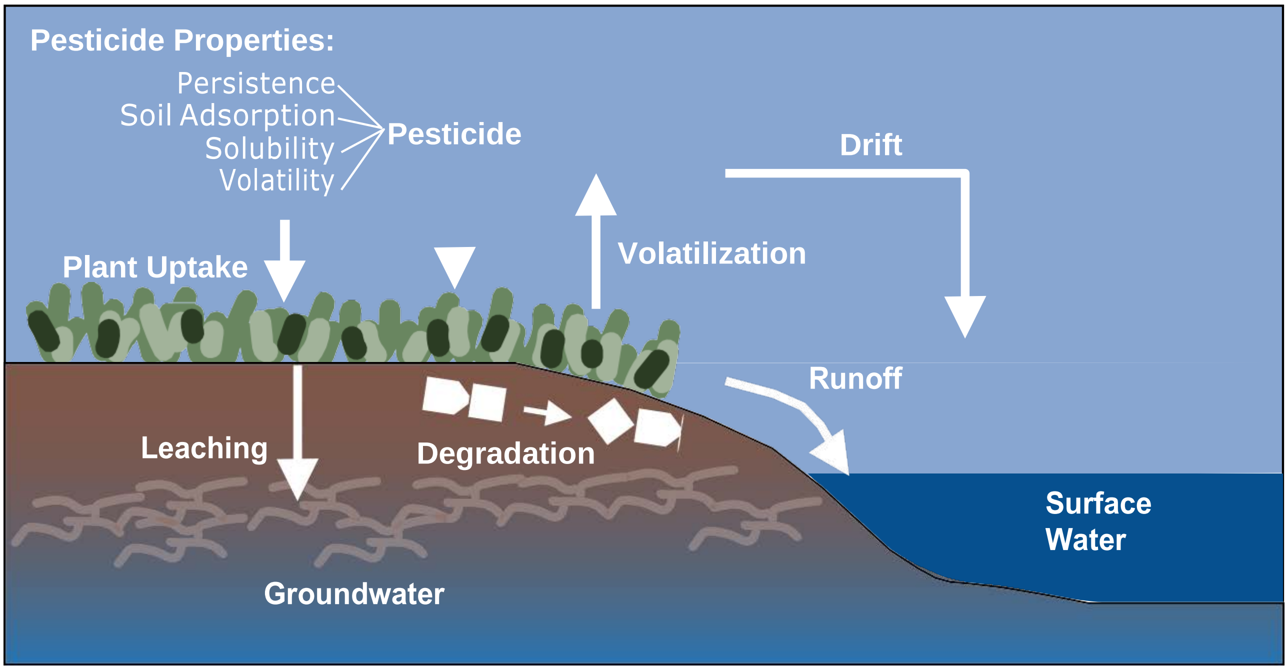

Figure 4. Factors influencing pesticide transport and its impact on water quality.

selecting pesticide products to use in areas mapped as medium or highly sensitive to leaching. However, because field scale properties can vary, this map should be used only as a starting point for further consideration. In sensitive areas, applicators should seriously consider whether to use pesticides with groundwater advisory statements (See Appendix Table A. for a list of common pesticides used in Colorado with groundwater advisory statements). The permeability of subsurface layers affects the rate of groundwater recharge and subsequent contamination if any pesticide is carried in percolating water (Figure 4). Regions with highly permeable materials, such as those found over alluvial aquifers in Colorado, are particularly susceptible to contamination. These vulnerable areas merit careful pesticide selection and application methods, especially where irrigation may result in excess water for leaching.

Additional pesticide information found here: http://npic.orst.edu/ingred/products.html

Site Features

Soil Characteristics

Soil properties and water management can significantly affect pesticide movement in the environment. The most significant soil properties influencing pesticide behavior are:

- Organic matter content
- Texture
- Structure and macropores
- Moisture content
- pH
- Cation exchange capacity

Soil organic matter (SOM) content is an important soil property affecting pesticide adsorption. Pesticides can be held in soil onto organic matter or clay particles by the process of adsorption.

Soil texture refers to the proportion of sand, silt, and clay particles in the soil. Texture affects the surface charge and the surface area for pesticide adsorption.

Pesticides with a high K_{OC} are strongly attracted to the surface of organic matter and are less likely to leach in soils that are high in organic matter. Applicators working on soils with less than 1% organic matter should be aware of the possibility of pesticide leaching.

Soils with higher clay content have a greater ability to adsorb pesticides, but they are more susceptible to runoff and need to be managed accordingly. Sandy soils leach more readily and provide fewer sites for pesticide adsorption. Soils with a high sand content should be managed carefully, with minimal use of persistent or very mobile pesticides.

Soil structure - the way soil particles are aggregated - significantly affects water movement and may allow pesticides to leach through the profile before they can be adsorbed or degraded. Large soil cracks or openings (macropores) caused by heaving, roots, or fauna can cause rapid pesticide movement, even in fine soils with high organic matter. Soils characterized by high numbers of macropores are poor candidates for chemigation (See Glossary for definition) because the chemical can move rapidly downward below the root zone.

Soil properties inherent to a site are difficult, if not impossible, for a producer to change. However, specific soil characteristics can alert producers to the likelihood of pesticide runoff or potential leaching at their sites. One of the most significant factors affecting runoff or leaching is the soil moisture condition at the time of pesticide application.

In the semi-arid climate of Colorado, producers can manage pesticide application and irrigation to mitigate pesticide loss. Pesticides with medium or high mobility should not be applied to a saturated soil or just prior to a heavy irrigation. Alternative pest management strategies should be considered when the soil moisture status increases the probability of runoff or leaching.

In addition to soil properties, other features of the application site can affect the potential for pesticide movement.

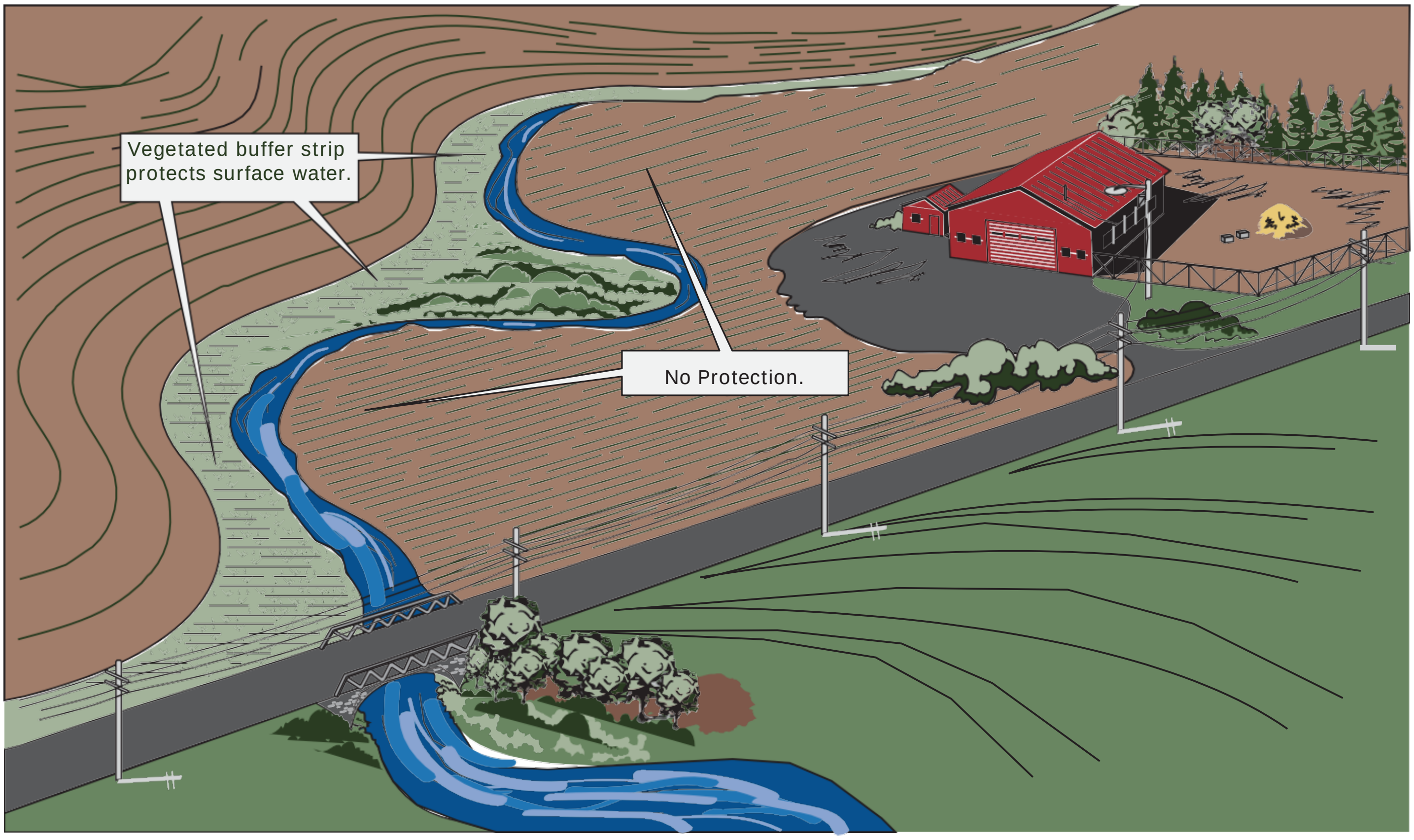

Figure 5. Pesticide application buffer zone to protect surface water

The site characteristics of greatest concern include:

- Depth to groundwater
- Proximity to surface water
- Topography
- Aquifer and overburden characteristics
- Climate and irrigation

Distance to water is one of the most important site features to consider when evaluating pest management decisions. When the water table is close to the soil surface (less than 30 feet), contamination of groundwater is much more likely than when groundwater resources are deep. Surface water proximity should also be considered prior to pesticide application. Observe a setback or buffer zone located a safe distance from wells, streams, ponds, and lakes (Figure 5), and do not apply pesticides in these zones. The actual setback required will depend on the slope, the mobility of the chemical, and the likelihood of runoff.

As shown in Figure 3, groundwater sensitivity to pesticide contamination varies greatly across Colorado due to depth to water table, permeability of materials overlying aquifers, and availability of recharge for transport of contaminants (irrigation). The mapped areas are predominately agricultural, where the bulk of pesticides are used in an irrigated setting. Pesticide applicators should exercise extreme caution when mixing and/or applying pesticides in these sensitive areas, particularly when selecting pesticide products to use in areas mapped as medium or highly sensitive to leaching. However, because field scale properties can vary, this map should be used only as a starting point for further consideration. In sensitive areas, applicators should seriously consider whether to use pesticides with groundwater advisory statements (See Appendix Table A. for a list of common pesticides used in Colorado with groundwater advisory statements). The permeability of subsurface layers affects the rate of groundwater recharge and subsequent contamination if any pesticide is carried in percolating water. Regions with highly permeable materials, such as those found over alluvial aquifers in Colorado, are particularly susceptible to contamination. These vulnerable areas merit careful pesticide selection and application methods, especially where irrigation may result in excess water for leaching.

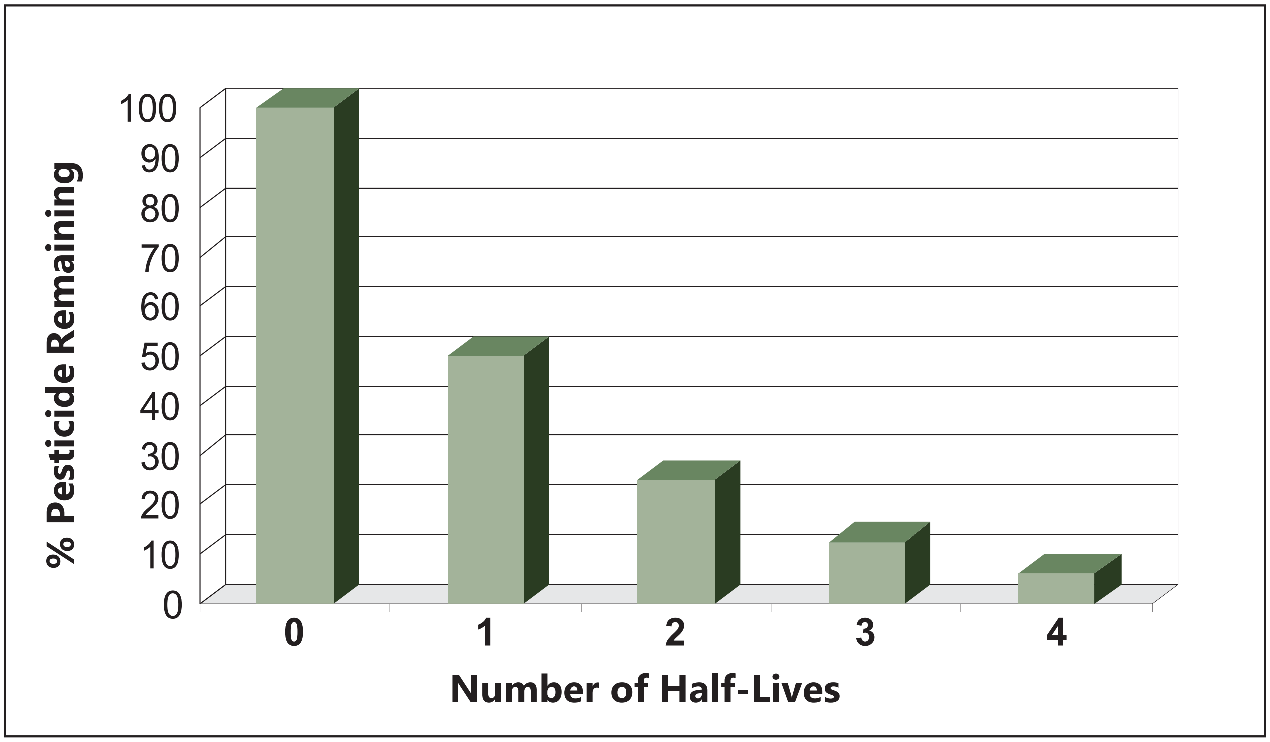

Figure 6. Half-life chart depicting that it takes multiple half-life periods for full pesticide degradation in the environment.

Soil properties	Effects on leaching*
Soil Texture	Sandier textures more susceptible to leaching .
Soil Organic Matter	Soils with higher SOM have a greater ability to adsorb pesticides.
Macropores	The presence of preferential flow paths (e.g. earthworm holes, root channels, cracks, etc.) in the soil profile can lead to deep percolation of dissolved pesticide regardless of texture and SOM content.
Slope	The greater the slope, the less time water has to percolate through the soil profile.
Pesticide properties	**Effects on leaching***
Half-life	The time it takes for half of the amount of applied pesticide to degrade. (Figure 6)
K_{OC}	The higher the K_{OC}, the more strongly the pesticide will adsorb to the soil particles
Solubility	The more soluble the pesticide, the more likely it will travel in solution via leaching or runoff.
Site features	**Effects on leaching***
Distance to groundwater	The greater the distance to groundwater, the more time /distance pesticides have to travel (and more time for degradation in the meantime) to reach that resource.
Permeable overburden	The more restrictive the layers are between the soil surface and the groundwater resource, the less likely it will be affected by leaching.
Irrigation water management	Any additional moisture that is applied beyond the active root zone increases the chances of leaching to groundwater.

Table 2. Factors Influencing Pesticide Leaching Potential

* These guidelines are only indicators that a hazard may exist. Actual leaching depends on the interaction of site and management factors.

Determining Pesticide Loss Potential

Pesticide applicators should evaluate all soil, site, and pesticide properties to determine the relative hazard to water resources that pesticide applications may pose. Table 2 lists factors that applicators should consider so that they can select pest management measures that are least likely to impact ground or surface water.

Pesticide Leaching and Runoff

For sites that are vulnerable to leaching, exercise caution when considering pesticides that are poorly adsorbed or that have long persistence in the environment. When possible, select pesticides with low toxicity to non-target organisms, short half-lives, and high adsorption.

This information is usually available from your chemical dealer, Extension agent, or crop adviser. Several computer models have been developed to predict pesticide movement and to help applicators select the most appropriate pest management strategy.

A Windows based pesticide-screening tool (WIN-PST) is available through the USDA- NRCS. WIN- PST is a pesticide environmental risk screening tool that evaluates the potential for pesticides to move with water and eroded soil and affect non-target organisms. WIN-PST software and installation instructions are available for download at and assistance is also available through your local NRCS Field Office.

https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/water/quality/?cid=stelprdb1044769

Runoff

Pesticides have routinely been found in surface waters receiving agricultural runoff, particularly after heavy spring rainfall or surface irrigation. This suggests that the proper management of pesticides should focus on good IPM techniques for avoiding the need for pesticides or reducing the quantities needed. Once the decision to use pesticides has been made, attention to timing, application methods, weather, irrigation water management and other BMPs should be paramount at the time of application.

Additionally, land management practices, such as reduced tillage, strip tillage, and no-till, are important for protecting surface water quality. Where appropriate, vegetated buffers should be established strategically along field edges that drain directly to streams and lakes.


Figure 7. Pesticide Application

Contact local NRCS personnel for buffer design criteria to protect surface water from pesticide runoff (Figure 5).

Conservation tillage practices that increase the amount of crop residues on the soil surface can reduce runoff volume and velocity, which results in less erosion and less pesticide movement on the surface. Strongly adsorbed chemicals, such as paraquat, tend to adhere tightly to soil particles and will move on eroding sediments. No-till or reduced tillage systems are highly recommended on all erosive soils. However, in some cases increased macro porosity and infiltration, coupled with increased herbicide use, may favor pesticide leaching. Where groundwater is shallow and domestic wells are nearby, these trade-offs should be assessed.

Pesticide Use Practices

Although pesticide use is a standard practice in most agricultural operations, most producers are adopting an Integrated Pest Management (IPM) approach. IPM techniques can reduce pesticide use to the minimum amount necessary, yet still maximize profits. IPM combines chemical control with Prevention, Avoidance, Monitoring and Suppression (PAMS) activities to form a comprehensive program for managing pests. This approach emphasizes preventive measures to maintain pests below the economic threshold while using the minimum amount of pesticide necessary.

Prevention is the practice of keeping a pest population from infesting a field or site and includes such tactics as using pest-free seeds and transplants, preventing weeds from reproducing, irrigation scheduling to avoid situations conducive to disease development, cleaning tillage and harvesting equipment between fields or operations, using field sanitation procedures, and eliminating alternate hosts or sites for insect pests and disease organisms.

Avoidance may be appropriate when pest populations exist in a field or site, but a cultural practice avoids pest impact to the crop. Examples include crop rotation, choosing cultivars with genetic resistance to pests, using trap crops or pheromone traps, choosing cultivars with maturity dates that may allow harvest before pest populations develop, and not planting areas of fields where pest populations are likely to cause crop failure.

Monitoring and identification of pests should be performed as the basis for suppression activities. Monitoring can include surveys or scouting programs, trapping, or weather monitoring and soil testing where appropriate. Records should be kept of pest incidence and distribution to help determine the most appropriate crop rotation, economic thresholds, and suppressive action. Proper pest identification and using the correct pesticide at the time of maximum pest susceptibility is foundational to an effective IPM program.

Suppression of pest populations becomes necessary to avoid economic loss if monitoring indicates that prevention and avoidance tactics are not successful. Suppression activities include cultural, physical, biological and chemical controls. Changing your pest management strategy to an IPM program may involve modifying tillage, fertility, cropping sequence, and sanitation practices. This may require some experimentation and perhaps even professional advice. Additional information, practical guidelines and tools for using IPM are available online both in the High Plains IPM Guide https://wiki.bugwood.org/HPIPM:Main_Page and at the Western IPM Network http://westernipm.org/

Restricted Use Pesticides

When pesticides are required to control pests, it is important to use application techniques that minimize potential water quality impacts. All commercial applicators should be certified through the Colorado Department of Agriculture (CDA) and remain current in new pest management techniques and developments. Certification through CDA is required for all commercial applicators and for distribution and application of Restricted Use Pesticide (RUP) products. Information about CDA's Pesticide Applicator Program is available at:
https://www.colorado.gov/pacific/agplants/pesticides

A separate licensing category exists for private applicators who apply an RUP. Any person who uses or supervises the use of an RUP on property owned or leased by the applicator or the applicator's employer must be a licensed private applicator. A licensed private applicator may apply RUP's for another producer for agricultural commodity production only if the compensation is limited to the trading of personal services between the applicator and the other producer. Certification for private applicators is conducted by CDA.

Avoid pesticide applications during adverse weather, especially during windy and wet conditions. Do not apply volatile chemicals such ad 2,4-D ester or methyl parathion under high temperature conditions.

Pesticide Application Practices

Pesticides should be applied at a time when they will be most effective against the crop pest. Pest cycles are influenced by temperature and moisture conditions. In many cases, pests under dormant or stressed conditions may not be susceptible to pesticide treatments. Lower pesticide rates reduce the total amount of chemicals in the environment; therefore, apply the lowest labeled pesticide rate that adequately controls pests. Rotate pesticides among chemical families to minimize pest resistance. IPM does not rely on continuous use of a single pesticide or pesticide family (Appendix Table B).

The application method used to apply pesticides can influence leaching or runoff potential. Soil injection or incorporation makes the pesticide more available for leaching, but less likely to cause surface water contamination. In general, pre-plant and pre-emergence treatments on clean tilled soil are more subject to surface loss than post-emergence treatments, when crop cover reduces runoff. Foliar insecticide and post-emergence herbicide treatments may reduce the potential for chemical movement because of rapid absorption by plants. Additionally, many of the foliar or post-emergence chemicals are less persistent and can sometimes be used effectively at lower rates.

Banding herbicides over the crop row is a BMP that can significantly reduce chemical costs while maintaining yields. Many producers are using a 10- to 15-inch band, reducing total herbicide use by 50% or more. Banding may require an extra cultivation and slightly more management, but it does not involve sophisticated equipment or a large investment. Existing application and tillage equipment usually can be modified. Spot pesticide treatments in the pest-affected areas of a field can also control pests to within economic levels with much less chemical than broadcast applications. The reduced amount of pesticide used under band and spot applications can result in higher returns and less pesticide for potential leaching or runoff.

Broadcast Sprayer Calibration Formula

Gallons per acre = Gallons/nozzle/minute x 12 x 43560/nozzle spacing x speed (in feet per second)

Gallons/nozzle = Ounces collected in 1 minute from 1 nozzle/minute/128

Nozzle spacing = Distance in inches between nozzles on spray boom

Speed = mph x 88

Precision Farming Technology

Precision farming systems include information, technology, and decision support. In pest management, information can include the collection and mapping of pest populations in fields. Mapping of pests can be done manually or using technology such as a global positioning system (GPS) and geographic information systems (GIS) software. These maps, combined with known economic threshold levels for each crop, can be used to determine where spraying is necessary. A tractor equipped with the software, corresponding map, and a GPS unit can then be used to selectively spray the field. This requires that the GIS map, the GPS unit, and the tractor's sprayer unit all be connected so the boom will turn on and off as needed. A primary benefit of using GPS/GIS technology includes application maps for record keeping.

Lightbar navigation and/or auto-steer are another form of precision farming technology that can be used when applying pesticides. The lightbar consists of a row of LEDs (light-emitting diodes), a GPS receiver, and a microprocessor. This technology helps guide the applicator and reduces application overlap, overspray, and application costs.

Application Technology

Advances in pesticide application technology reduce pesticide use and increase application efficiencies. Precision farming technology enables accurate pesticide applications using GPS-controlled navigation. Application rate efficiencies are also improved with advanced boom flotation, nozzle design, sprayer electronics and controls, computer control with GPS and GIS, direct injection, and chemical mixing.

Calibration & Equipment Maintenance

Effective pesticide use requires uniform application of the correct amount of chemical and carrier. Under-application usually results in poor control, which may require retreatment. Over-application of pesticide seldom increases control and may result in crop damage and needless environmental risk in addition to being illegal.

Calibrate spray equipment prior to each application and maintain all equipment according to the manufacturer's recommendation. Check hoses, booms, tanks, and nozzles regularly for uneven wear and leaks or drips.

Information on proper calibration of field sprayers is available from a number of sources. Check with your local chemical dealer, crop consultant, or Extension agent for help calibrating your equipment properly. Also, the following links will direct you to equipment calibration and maintenance web sites:

Equipment calibration:
http://waterquality.colostate.edu/pestrecordbook.shtml

Equipment cleaning/maintenance:
http://extensionpublications.unl.edu/assets/pdf/g1770.pdf
https://ppp.purdue.edu/wp-content/uploads/2016/08/PPP-108.pdf

Advances in sprayer technologies have improved pesticide application efficiencies and effectiveness, reduced operator exposure to chemicals, and reduced over applications of product, which ultimately increases producer profitability.

Advances in Nozzles

Advances in nozzle design allow pesticide applicators to choose nozzles that match their needs. Application rate improvements are influenced by increases in plant coverage and more effective crop canopy penetration and pesticide adherence to plant surfaces. Air induction (inclusion) nozzles increase spray droplet size by mixing air into the spray solution, which lowers drift potential. When these droplets strike the spray target they release energy stored in bubbles, spreading out the droplet onto the target surface. This increases application efficiency and effectiveness. Angled nozzles enable under-canopy pesticide applications, making targeted applications effective. Advances in broadcast nozzle designs provide more uniform coverage with a broad range of operating pressures. Also, spray droplet size and spray patterns can now be adjusted from the cab to match application types and environmental conditions.

Modern materials used in boom construction allow for lighter-weight equipment with greater strength and flexibility. Boom suspension controls allow the operator to adjust boom float to match field conditions, which isolates the boom from the sprayer and allows flotation. This improves application efficiency by providing a more even application.

Chemical Mixing

Modern electronics has improved application accuracy with electronic flow meters, pressure gauges, speed sensors, and system computers. GPS with direct injection allows for targeted spraying. Sensor controlled systems engage application when the target is seen by the sensor, which is useful in orchards and reduces the amount of materials applied. Chemical mixing for spray applications has been a source of operator chemical exposure. Modern equipment designs offer chemical induction systems to enable liquid and dry chemical to be loaded into the system via a separate chemical tank as opposed to traditional tank mixing procedures. This enhances operator safety by improving chemical handling procedures, and it decreases carryover from improper cleaning of mixing tanks when changing rates or products. Operator safety should be paramount in any IPM program; advances in equipment design and functionality facilitate operator safety.

Recordkeeping

Keeping accurate records of all agricultural chemicals applied on your site will help you make informed management decisions. By law, records of all restricted use pesticides (RUP) must be maintained by operators for at least three years in Colorado (see https://www.ams.usda.gov/rules-regulations/pesticide-records). You can maintain records of non-restricted chemicals on the same form as the required records with minimal additional effort. This information has further value for use with crop and pest modeling programs and economic analyses. Records must be kept for all RUP applications and must include:

- Brand or product name
- EPA registration number
- Total quantity of pesticide applied
- Application date
- Location of restricted use pesticide applications (not farm address)
- Crop commodity, stored product, or site treated
- Size of treatment area
- Name of the certified private applicator performing and/or supervising the application
- Certification number of the private applicator

Other useful information to record includes:

- Weather data and irrigation water applied
- Description of pest problems
- Application rate of chemical and carrier
- Equipment calibration data

Colorado State University Extension and several other organizations have developed record-keeping forms for restricted use pesticides. Computer software is also commercially available to help producers and applicators maintain high-quality records.

For pesticide record- keeping forms, spread sheets and additional support please visit: http://waterquality.colostate.edu/pestrecordbook.shtml

Summary

Pesticides are currently an important component of most agricultural pest management strategies. The IPM approach can help producers minimize water quality impacts and manage pests economically. A number of BMPs are effective in reducing pesticide runoff and leaching. Additional benefits of these BMPs include reduction of soil erosion and nutrient losses.

Selection of least toxic chemical controls should be coupled with knowledge of site and chemical interactions. Sites with vulnerable water resources require selection of pesticides least likely to move off-target, or alternative pest management measures. Proper management of soils, water, and pesticides by agricultural producers can help reduce adverse water quality impacts.

Related source material from Colorado State University Extension

- Fact Sheet 5.003 Sprayer Calibration
- Fundamentals Fact Sheet 5.021
- XCM-176 Best Management Practices for Crop Pests
- XCM-178 Best Management Practices for Pesticides and Fertilizer Storage and Handling
  https://extension.colostate.edu/docs/pubs/crops/xcm178.pdf
- Colorado Pesticide Information Retrieval System
  http://npirspublic.ceris.purdue.edu/state/default.aspx
- CEPEP Fact Sheet: The Pesticide Label
  https://webdoc.agsci.colostate.edu/cepep/FactSheets/103pesticidelabel.pdf
- CEPEP Fact Sheet: Understanding the Material Safety Data Sheet
  https://webdoc.agsci.colostate.edu/cepep/FactSheets/104MSDS.pdf
- Colorado Department of Agriculture
  http://www.colorado.gov/ag
  (303) 869-9000

Note: The pesticide label always supersedes any educational material such as this publication. Always read and follow label instructions precisely. Data presented in this publication on commercial products are for educational purposes only. Reference to commercial products does not imply endorsement, nor is criticism implied of products not mentioned

Rocky Mountain Poison and Drug Center

1-800-222-1222
Denver, Colorado
www.rmpdc.org

For more information about pesticide management or specific inquiries about BMPs, contact Colorado State University Extension or visit www.csuwater.info. CSU publications, programs, and specialists are available to help you answer questions about water quality.

BMPs for Agricultural Pesticide Use

1. Obtain thorough training and the appropriate certification prior to applying any pesticide.

2. Always follow pesticide label directions and read all instructions, particularly precautionary statements, prior to chemical mixing and application. All pesticide applications must follow label specifications and must be applied only to the crops for which the product is registered for use.

3. Keep accurate and timely pest and pesticide records. See Pesticide Recordkeeping Form for suggested format.

4. Consider the effects of pest control measures on the environment and non-target organisms. Minimize chemical reliance by rotating crops and using physical, biological, or cultural pest management controls whenever feasible.

5. Follow refuge requirements for biotech cultivars to avoid resistance development in target pests.

Pesticide Selection BMPs

6. Avoid the overuse of preventive pesticide treatments. Base pesticide application decisions on site-specific pest scouting and indicators of economic return.

7. Select least toxic and less persistent pesticides when feasible.

8. Avoid overuse of herbicides with common modes of action (Appendix Table B). Chemicals within the same family have similar modes of action and should be rotated to avoid weed resistance particularly with herbicide tolerant cultivars.

9. Consider pesticide and target site characteristics to determine suitability of the pesticide at that location. Knowledge of pesticide persistence, mobility, and adsorption should be included in pesticide selection (Appendix Table A). Chemical applicators should know the characteristics of the application site, including soil texture, organic matter, topography, and proximity to ground and surface water. Contact your local NRCS office for further information about the soils on your site and possible pesticide interactions.

Pesticide Application BMPs

10. Maintain application equipment in good working condition and calibrate equipment frequently to ensure that pesticides are applied at recommended rates. Replace all worn components of pesticide application equipment, especially nozzles, prior to application.

11. Ensure that the pesticide applicator knows the exact field location to be treated. Post warning signs around fields that have been treated, in accordance with local, state, and federal laws. Follow the established re-entry interval as stated on the pesticide label.

12. Employ application techniques that increase efficiency and allow the lowest effective labeled application rate. Use band and spot applications of pesticides where appropriate to reduce environmental hazards and treatment costs.

13. Optimize pesticide rate, timing, and placement to avoid the need for re-treatment. Additionally consider optimum ambient temperatures specific to the product applied.

14. Avoid overspray and chemical drift, especially when surface water is in close proximity to treatment area. Avoid applications if wind speed favors drift beyond the intended application area. Increasing nozzle size and lowering boom pressure will increase droplet size and help reduce drift. Always recalibrate following equipment adjustments or modifications.

15. Time pesticide application in relation to soil moisture, anticipated weather conditions, and irrigation schedules to achieve the greatest efficiency and reduce the potential for off-site transport. Avoid pesticide application when soil moisture status or scheduled irrigation increases the possibility of runoff or deep percolation. After application, manage irrigation to reduce the possibility of erosion, runoff and/or leaching, which may transport pesticide from the target site. Numerous tools are available to support irrigation scheduling including CSU's WISE Irrigation Scheduler: http://wise.colostate.edu/

16. Establish buffer zones so pesticide is not applied within 50–100 feet of wells and surface water.

17. Apply pesticides in a manner that will minimize off-target effects.

18. Avoid repetitive use of the same pesticide or pesticides of similar chemistry and modes of action to reduce the potential for pesticide resistance development and shifts in the pest spectrum.

19. Ensure that backflow prevention devices are installed and operating properly on irrigation systems used for applying pesticides.

20. Use GPS/GIS technology, where appropriate, to aid in pest mapping, pesticide application precision and record keeping.

21. Use Monitoring and economic pest threholds to reduce the amount of pesticide applied with preventative treatments because applications are based on monitoring that determines when a pest population exceeds a previously determined economic threshold.

Pesticide Safety BMPs

22. Read and follow label safety directions, maintain appropriate Material Safety Data Sheets (MSDS), and become certified prior to applying restricted use pesticides.

23. Wear the appropriate protective equipment specified on the pesticide label to minimize unnecessary exposure to pesticide. Be sure to clean protective gear after each day's use.

24. Provide emergency hand and eye wash facilities for personnel working in chemical storage, mixing, and treatment areas. Develop a safety plan that includes information about poison centers and emergency treatment centers. Post emergency response phone numbers in highly visible places near areas where chemical handling occurs.

25. Know what to do in case of accidental pesticide poisoning. Have an emergency response kit available when handling pesticides. Check the product label for instructions and call the nearest poison center in the event a pesticide is swallowed or when pesticide exposure has occurred. Product labels often include a telephone number where expert information is also available. Take the pesticide label to the attending physician if you need treatment.

26. Follow all Worker Protection Standard (WPS) requirements and postings as specified by the label under "Directions for Use or Agricultural Use Requirements," which includes requirements for personal protective equipment, restricted entry and posting.

27. Program emergency response numbers into your cell phone when involved with pesticide handling.

28. XCM-202 Pesticide Record Book for Private Applicators

Glossary

Adsorption
The process by which atoms, molecules, or ions are taken up from the soil solution or soil atmosphere and retained on the surfaces of solids through chemical or physical binding. Defined by an adsorptivity constant called Koc.

Backflow
Flow in the reverse direction of normal flow.

Buffer zone
An area set aside from chemical applications and designed to hold influx of substances due to wind and water erosion by physical and chemical detainment.

Calibration
The process of adjusting equipment to deliver the desired amount of a substance when application occurs.

Chemigation
The application of pesticide through an irrigation system.

Conservation tillage
A tillage system that uses specially designed equipment to retain crop residue on the soil surface to lower erosion potential and aid in water conservation.

Degradation rate
The amount of time it takes for the half life of a substance to occur.

Fungicide
A chemical product or biological organism used to kill or inhibit fungi or fungal spores.

Half life
Length of time it takes for the quantity of a substance to decay to half its original mass. Persistence is significant, because the longer a chemical remains in the environment the greater the probability the chemical will move to off-target locations or damage non-target organisms.

Herbicide
A chemical product designed to kill unwanted plants

Insecticide
A chemical product designed to kill unwanted insects.

Leaching
Movement of a chemical downward through the soil.

Macropores
Large soils pores formed by cracks, root holes, worm channels or other physical or biological mechanisms that can be responsible for rapid infiltration and percolation of water and dissolved chemicals below the rootzone.

Nonpoint contamination
Contamination that occurs when a single identifiable point of contamination is not defined.

Nontarget organism
An organism, such as a plant, insect, animal, or microbe, that is not the target of pesticide application but is present within the management area.

Off-target location
An area that is not within the application management area but is still impacted by the pesticide.

Overspray
Pesticide application that occurs where not intended or planned in an area adjacent to a treatment area.

Pesticide detection
The detection of a pesticide in a sample.

Percolating water
Water moving or seeping downward through the soil from precipitation and/or irrigation.

Point-source contamination
Contamination that occurs where a single point of contamination can be identified.

Post-emergence treatment
The application of pesticide to an emerged crop

Pre-emergence treatment
The application of pesticide to the soil or plant residue prior to crop emergence.

Restricted Use Pesticide (RUP)
A pesticide that is not available for use by the general public due to its acute human toxicity, accident history, potential for or history of groundwater contamination, toxicity to vulnerable nontarget plants or animals, or is a fumigant or carcinogenic or mutagenic product.

Solubility
A measure of how much substance can solubilize in a given amount of water.

Vapor drift
The movement of a pesticide in its gaseous state from the point of application.

Volatility
The measure of a pesticide's proneness to vaporize through evaporative processes as influenced by temperature, relative humidity, and solar radiation.

Appendix

Appendix Table A. Pesticide properties, risk ratings and groundwater advisory identifications.* Values for adsorptivity and solubility are of special interest because they influence the likelihood of off-target effects.

Key

H= High

I = Intermediate

L = Low

VL= Very Low

Example Trade Name	Active Ingredient Name	Surface Water Advisory [1]	Ground Water Advisory [1]	Detected in Colorado GW [2]	Solubility (mg/L) [3]	Soil Adsorption (Koc mL/g) [3]	Half life (Days) [3]	Pestcide Leaching Potential [4]	Pesticide Solulable Runoff Potential [4]	Pesticide Adsorbed Runoff Potential [4]
Aatrex	Atrazine		X	X	33	100	60	H	H	I
Accent	Nicosulfuron			X	22,000	30	21	H	I	L
Acrobat WP, Forum	Dimethomorph				19	428	92	I	H	I
AGLOGIC 15GG	Aldicarb			X	6,000	30	30	H	I	L
Ally	Metsulfuron-methyl				9,500	35	120	H	H	I
Alto	Cyproconazole		X		93	364	142	H	H	I
Amber	Triasulfuron		X		815	60	59.1	H	H	I
Amiral, Bayleton	Triadimefon	X	X		71.5	300	26	I	H	L
Anthem Flex	Pyroxasulfone	X	X		3.48	129	21	I	I	L
Anthem Flex	Carfentrazone	X	X		12	866	4	L	I	L
Arsenal	Imazapyr			X	11,000	100	90	H	H	I
Asana	Esfenvalerate				0.002	5,300	35	L	I	I
Assert	Imazamethabenz-methyl		X	X	1,370	66	45	H	H	I
Avadex BW, Far-Go	Triallate	X	X		4	2,400	82	L	H	H
Axiom	Flufenacet	X	X		56	401	199	H	H	I
AXLE 2E	Mefenoxam		X		26,000	660	8	L	I	L
Balance	Isoxaflutole	X	X		6.2	145	1	L	I	L
Banvel	Dicamba		X	X	4,500	5	14	H	I	L
Basagran, Storm, Rezult	Bentazon		X	X	570	55	13	I	I	L
Basta, Ignite, Cheetah, Finale	Glufosinate-ammonium	X			1,370,000	100	7	L	I	L
Bayleton 50	Triadimefon		X		71.5	300	26	I	H	L
Bifenthrin	Bifenthrin				0.1	240,000	26	VL	L	I
Bladex, SD 15418	Cyanazine				170	190	14	I	I	L
Bravo	Chlorothalonil	X	X		0.6	1,380	30	L	I	I

Example Trade Name	Active Ingredient Name	Surface Water Advisory [1]	Ground Water Advisory [1]	Detected in Colorado GW [2]	Solubility (mg/L) [3]	Soil Adsorption (Koc mL/g) [3]	Half life (Days) [3]	Pestcide Leaching Potential [4]	Pesticide Solulable Runoff Potential [4]	Pesticide Adsorbed Runoff Potential [4]
Broadstrike, Python	Flumetsulam		X		5,650	28	47	H	H	I
Buctril, Bronate	Bromoxynil		X		90	302	8	L	H	L
Butyrac, Embutox	2,4-DB		X	X	46	440	5	L	H	L
Cadet	Fluthiacet-methyl	X	X		0.78	100	8	I	I	L
Capreno	Thembotrione		X		28.3	50	40	H	H	L
Capreno	Thiencarbazone-methyl		X		172	148	29	I	I	L
Caramba	Metconazole	X	X		30.4	1,875	265	L	H	H
Casoron	Dichlobenil		X		21.2	400	60	I	H	I
Certain, Maverick	Sulfosulfuron		X		1,627	33	45	H	H	I
Classic	Chlorimuron-ethyl				1,200	110	40	H	H	L
Comite	Propargite				0.5	4,000	56	L	I	H
Coragen	Chlorantraniliprole	X	X	X	0.972	330	509	H	I	I
Curalan, Touche	Vinclozolin	X	X		1,000	100	20	I	I	L
Curtail	Clopyralid		X	X	143,000	5	30	H	I	L
Cygnus	Kresoxim-methyl	X	X		2	100	4	L	I	L
Dacthal	Dimethyl tetrachloroterephthalate	X	X	X	0.5	5,000	100	L	I	H
Dazzel	Diazinon		X	X	60	1,000	40	L	H	H
DDVP, No-pest, Vapona	Dichlorvos			X	10,000	30	0.5	VL	I	L
Dichlorprop, Celatox DP, Cornox RK	2,4-DP, dimethylamine salt		X	X	200,000	26	10	I	I	L
Dimethoate	Dimethoate	X	X	X	39,800	20	7	I	I	L
Dipterex, Dylox, Neguvon	Trichlorfon				120,000	10	10	H	I	L
Distinct	Dicamba, sodium salt		X	X	400,000	2	14	H	I	L
Distinguish, Scala	Pyrimethanil				121	508	30.5	I	I	L
Disyston	Disulfoton				25	600	30	I	H	L
DPX-T5648, Oust	Sulfometuron methyl	X	X		70	78	20	I	H	L
Drive, Facet	Quinclorac		X	X	0.065	50	450	H	I	I
Dual	Metolachlor	X	X	X	530	200	90	H	H	I
Dynex	Diuron			X	42	480	90	I	H	I
Endosol	Endosulfan				0.32	12,400	50	VL	I	H
Eptam	EPTC				344	200	6	L	I	L
Establish	Sodium diflufenzopyr	X	X	X	5,850	292	55	I	H	I
Ference	Cyantraniliprole	X	X		14.2	241	34	I	H	L

Example Trade Name	Active Ingredient Name	Surface Water Advisory [1]	Ground Water Advisory [1]	Detected in Colorado GW [2]	Solubility (mg/L) [3]	Soil Adsorption (Koc mL/g) [3]	Half life (Days) [3]	Pestcide Leaching Potential [4]	Pesticide Soluble Runoff Potential [4]	Pesticide Adsorbed Runoff Potential [4]
Furadan	Carbofuran		X		351	22	50	H	H	I
Garlon 3A	Triclopyr		X		440	68	13	I	I	L
GEM, COMPASS	Trifloxystrobin		X		0.61	2709	5	L	I	I
Gesamil, Milogard, Primatol P	Propazine			X	8.6	154	135	H	H	I
Gramoxone	Paraquat dichloride				620,000	100,0000	1000	VL	L	H
Graslan, Spike	Tebuthiuron	X	X	X	2500	80	360	H	H	I
Harness	Acetochlor	X	X	X	282	156	14	I	I	L
Hyvar	Bromacil		X	X	700	32	60	H	H	I
Imidacloprid 4F	Imidacloprid		X	X	610	225	174	H	H	I
Imprelis/Method	Aminocyclopyrachlor		X		4,200	28	100	H	H	I
Invader	Propoxur				1800	30	30	H	I	L
Karate	lambda-Cyhalothrin				0.005	180,000	30	VL	L	I
Lannate, Nudrin	Methomyl	X	X		58,000	72	30	H	I	L
Larvadex, Trigard	Cyromazine		X	X	136,000	200	150	H	H	I
Lasso	Alachlor		X	X	240	170	15	I	I	L
LEVITY	Acifluorfen		X		250,000	113	14	I	I	L
Lindane, Gammexene	Lindane			X	7	1,100	400	I	H	H
Linex	Linuron	X	X	X	75	400	60	I	H	I
Lorsban	Chlorpyrifos			X	0.4	6,070	30	L	L	I
Lucento	flutriafol	X	X		95	205	939	H	H	I
Mach 2	Halofenozide				12.3	250	219	H	H	I
Malathion	Malathion	X		X	130	1,800	1	L	L	L
Manzate	Maneb				6	2,000	70	L	H	H
Manzate 200	Mancozeb				6	2,000	70	L	H	H
MCPA Amine	MCPA		X		825	110	25	I	I	L
Mecoprop dimethylamine salt	MCPA, dimethylamine salt		X		866,000	20	25	H	I	L
Metasystox-R	Oxydemeton-methyl			X	1,000,000	10	10	H	I	L
Methyl Parathion	Parathion				24	5,000	14	L	I	I
Milestone	Aminopyralid		X	X	212,000	13	35	H	I	L
Mocap, Prophos	Ethoprop			X	750	70	25	H	I	L
Monument 75WG	Trifloxysulfuron		X		5,016	29	30	H	I	L
Nemacur	Fenamiphos			X	400	100	50	H	H	I

Example Trade Name	Active Ingredient Name	Surface Water Advisory [1]	Ground Water Advisory [1]	Detected in Colorado GW [2]	Solubility (mg/L) [3]	Soil Adsorption (Koc mL/g) [3]	Half life (Days) [3]	Pestcide Leaching Potential [4]	Pesticide Solulable Runoff Potential [4]	Pesticide Adsorbed Runoff Potential [4]
Nortranese, Nortron, Prograss	Ethofumesate				50	340	30	I	H	L
Orion	Florasulam		X		6,360	22	8.5	I	I	L
Outlook	Dimethenamide-ESA	X	X	X	1,449	241	31	I	I	L
Palladium	Cyprodinil	X	X		20	5,000	60	L	H	H
Palladium	Fludioxonil	X	X		1.8	1614	440	I	H	H
Peak	Prosulfuron	X	X		4,000	14	62	H	H	I
Permethrin	Permethrin, mixed cis,trans	X			0.006	100,000	30	VL	L	I
Permit	Halosulfuron-methyl		X		10.2	109	26.7	I	H	L
Plateau	Imazapic	X	X	X	2,150	4,200	232	L	H	H
Platinum	Thiamethoxam	X	X	X	4,100	56	39	H	H	L
Poncho	Clothianidin		X	X	327	166	832	H	H	I
Pramitol	Prometon			X	720	150	500	H	H	I
Princep	Simazine		X	X	6.2	130	60	H	H	I
Proline 480 SC, Provost 433 SC	Prothioconazole	X	X		300	300	225	H	H	I
Prowl	Pendimethalin				0.275	5,000	90	L	I	H
Pursuit	Imazethapyr		X	X	1,400	52	90	H	H	I
Pyridate	Pyridate				1.49	223,800	2	VL	L	I
Quadris, Azoxystar	Azoxystrobin	X	X	X	6.7	589	181	I	H	I
Raptor, Beyond, Clearcast	Imazamox			X	626,000	67	17	I	I	L
Ridomil	Metalaxyl	X	X	X	8,400	50	70	H	H	I
Ro-Neet	Cycloate				95	430	30	I	H	L
Roundup	Glyphosate				1,2000	1,424	24	L	I	I
Safari	Dinotefuran		X	X	39,830	26	82	H	H	I
Sencor, Lexone	Metribuzin		X	X	1,220	60	40	H	H	L
Sevin	Carbaryl				120	300	10	L	I	L
Shafen	Fomesafen		X		700,000	60	100	H	H	I
Sharpen	Saflufenacil	X	X		2,100	300	18	I	I	L
Sinbar	Terbacil	X	X		710	55	120	H	H	I
Solicam	Norflurazon	X	X	X	28	600	90	I	H	I
Sonalan	Ethalfluralin				0.3	4,000	60	L	I	H
Spartan	Sulfentrazone	X	X	X	780	43	541	H	H	I
Specticle 20 WSP	Indaziflam	X	X		4.4	900	180	I	H	I

Example Trade Name	Active Ingredient Name	Surface Water Advisory [1]	Ground Water Advisory [1]	Detected in Colorado GW [2]	Solubility (mg/L) [3]	Soil Adsorption (Koc mL/g) [3]	Half life (Days) [3]	Pestcide Leaching Potential [4]	Pesticide Solulable Runoff Potential [4]	Pesticide Adsorbed Runoff Potential [4]
Surveil	Cloransulam methyl	X	X		3,430	30	11	I	I	L
Tebucon 3.6F	Tebuconazole	X	X		36	1,079	84	I	H	H
Tebufenozide, Confirm	Tebufenozide		X		0.83	572	400	H	I	I
Telar	Chlorsulfuron			X	7,000	40	40	H	H	L
Temik	Aldicarb sulfoxide				6,000	30	30	H	I	L
Tordon	Picloram	X	X	X	430	13	90	H	H	I
Tower	Dimethenamide-P				1,449	241	31	I	I	L
Treflan	Trifluralin				0.3	8,000	60	L	I	H
Trinity	Triticonazole				8.4	374	300	H	H	I
Ultra Blazer	Acifluorfen		X		250,000	113	54	H	H	I
Velpar	Hexazinone		X	X	33,000	54	90	H	H	I
Vydate C-LV	Oxamyl	X	X		282,000	25	4	L	I	L
Weed B Gone	2,4-D, dimethylamine salt		X	X	796,000	20	10	I	I	L
Woverine Advanced	Pyrasulfotole	X	X		4,200	400	12	L	I	L

*Sources according to table headings

1. "Surface Water Advisory, Ground Water Advisory." Product label from: Crop Database Management System 2020 https://www.cdms.net/
2. "Detected in Colorado Groundwater" AWQP Database: https://erams.com/co_groundwater/
3. "Solubility, Soil Adsorption, Half life." WIN-PST 2020. http://go.usa.gov/Kok
4. "Pesticide Leaching, Pesticide Soluble and Adsorbed Runoff Potential." NRCS Pesticide Database, 2009. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/nra/nri/results/?cid=nrcs143_014167

Appendix Table B. Herbicide Families and Selected Herbicides. Source: Cropwatch Corn and Soybean Herbicide Chart. https://cropwatch.unl.edu/documents/Corn%20and%20Soybean%20Herbicide%20Chart.pdf

Family	Common name	Trade name(s)
Amino acid synthesis inhibitors:		
Imidazolinones	Imazamethabenz	Assert
	Imazapyr	Arsenal
	Imazethapyr	Pursuit
Sulfonylureas	Chlorsulfuron	Glean
	Metsulfuron	Ally, Escort
	Prosulfuron	Peak
	Thifensulfuron+Tribenuron	Harmony Extra Express
	Tribenuron	
Amino Acid Derivatives	Glyphosate	Roundup Ultra
Cell Membrane Disruptors:		
Bipyridyliums	Paraquat	Gramoxone, Cyclone
	Diquat	Reglone
Growth Regulators:		
Phenoxy-acetic Acids	2,4-D	2,4-D Amine
	MCPA	MCPA Amine
Benzoic Acid	Dicamba	Banvel
Pyridines	Clopyralid	Stinger, Curtail
	Picloram	Tordon
Lipid Synthesis Inhibitors:		
Aryloxyphenoxypropionate	Diclofop	Hoelon
	Fenoxaprop	Acclaim
Cyclohexanedione	Sethoxydim	Poast
	Clethodim	Select
Nitrogen Metabolism		
None Accepted	Glufosinate	Liberty
Photosynthetic Inhibitors:		
Triazine	Atrazine	Aatrex
	Prometon	Pramitol
Triazinone	Metribuzin	Sencor
	Hexazinone	Velpar
Uracil	Terbacil	Sinbar
	Bromacil	Hyvar
Phenylurea	Diuron	Karmex, Diurex
	Tebuthiuron	Spike
Benzothiadiazole	Bentazon	Basagran
Benzonitriles	Bromoxynil	Buctril, Bronate, Bison, Moxy
Phenyl-pyridazine	Pryidate	Tough
Pigment Indicators		
Isoxazolidinone	Clomazone	Command
Isoxazole Pyrazolone Triketone	Isoxafutole	Balance Flexx
	Mesotrione	Callisto
	Tembotrione	Laudis
Seedling Growth Inhibitors:		
Shoot Inhibitors (Carbamothioates)	Triallate	Buckle, Far-Go
	Cycloate EPTC	Ro-Neet
		Eradicane, Eptam
Shoot and Root Inhibitors (Acetamide)	S-metolachlor	Dual
	Propachlor	Ramrod
	Acetochlor	Harness, Surpass
Microtubule Assembly Inhibitors (Dinitroanilines)	Trifluralin	Treflan
	Pendimethalin	Prowl

Agricultural Pesticide Use

Best Management Practices

Agricultural Water Quality Program

COLORADO STATE UNIVERSITY EXTENSION