KANSAS STATE UNIVERSITY AGRICULTURAL EXPERIMENT STATION AND COOPERATIVE EXTENSION SERVICE

Managing to Minimize Atrazine Runoff

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Funding for this publication provided by the Kansas Department of Health and Environment through Environmental Protection Agency Section 319 grant number C9007405-97.

Atrazine herbicide has been used for almost 40 years in Kansas for selective control of broadleaf and grass weeds in corn and grain sorghum. It is the most widely used herbicide in Kansas, being applied annually to approximately 79 percent of the corn (1996 survey) and 82 percent of the grain sorghum (1998 survey) acres (Table 1). Atrazine can be successfully applied using a broad range of application timings and tillage practices, and is one of the lowest cost herbicides on a per-acre basis. It can be applied early preplant, preplant incorporated, preemergence, or postemergence. Annual application rates range from 0.5 to 2.5 pounds active ingredient (a.i.) per acre, with statewide average rates of 1.16 pounds of active ingredient per acre for corn (1996 survey) and 1.24 pounds of active ingredient per acre for grain sorghum (1998 survey). Kansas State University studies have shown it to be one of the most effective soil-applied herbicides for season-long weed control in corn and grain sorghum, and, in many postemergence herbicide tank mix programs, an essential herbicide for cost-effective control.

Table 1.

Atrazine use in Kansas corn and grain sorghum fields

Crop	Percent of Acres Treated	Average Rate Used (lbs. a.i. per acre)
Corn	79	1.16
Grain Sorghum	82	1.24

Source: USDA Agricultural Statistics Service. Corn data from 1996 survey; sorghum data from 1998 survey.

Water Quality Concerns

Atrazine is a low cost per-acre herbicide, but there may be environmental costs that should be considered when using atrazine. In recent years there have been concerns about the levels of atrazine runoff entering surface waters. This particularly became a concern when the Environmental Protection Agency (EPA) announced that a maximum contaminant level for atrazine of 3 parts per billion (ppb) would be set, starting in 1994. This is an enforceable level for public drinking water systems and, according to the EPA, is a concentration that is safe to drink over a 70-year lifetime with no adverse effects. Municipal water treatment plants do not remove atrazine and other pesticides unless the water treatment system includes an activated carbon process. Adding this process increases the cost of the treatment facility and the day-to-day cost of water treatment.

The Kansas Department of Health and Environment (KDHE) has set an aquatic life standard for atrazine concentrations in Kansas surface water of 3 parts per billion. Several lakes, rivers, and streams in eastern and central Kansas routinely exceed the 3 parts per billion standard for brief periods during the spring and summer months as a result of runoff events that occur shortly after herbicide application.

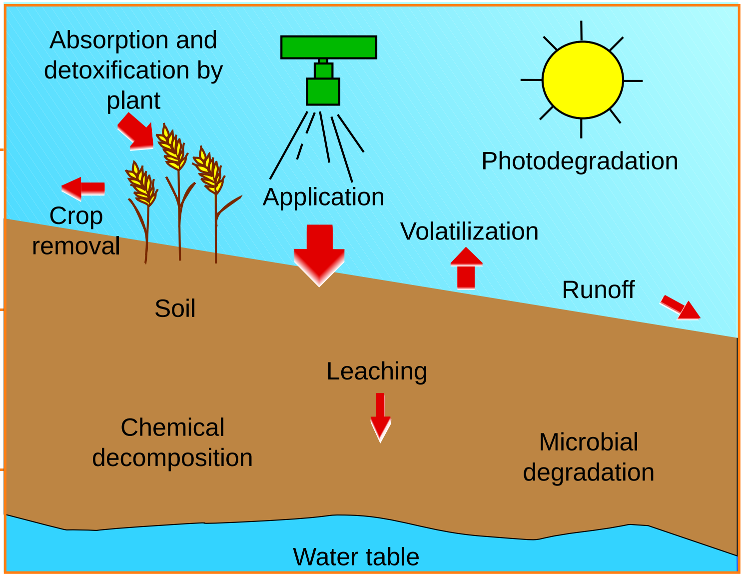


Figure 1. Pathways of atrazine degradation and loss.

In 1998, KDHE submitted its 303(d) list to EPA in which several lakes, rivers, and streams were identified as impaired by runoff of atrazine. For the atrazine-impaired watersheds, a Total Maximum Daily Load (TMDL) will be required to be set and an implementation plan will be developed to reduce atrazine levels. It is expected that the TMDL for atrazine will be reached by voluntary management practices by farmers. However, if atrazine levels are not brought into compliance within a reasonable period of time, regulatory controls may be implemented. Therefore, it is imperative that atrazine best management practices (BMPs) be adopted by farmers. Adoption and use of atrazine BMPs will minimize atrazine loss from crop fields.

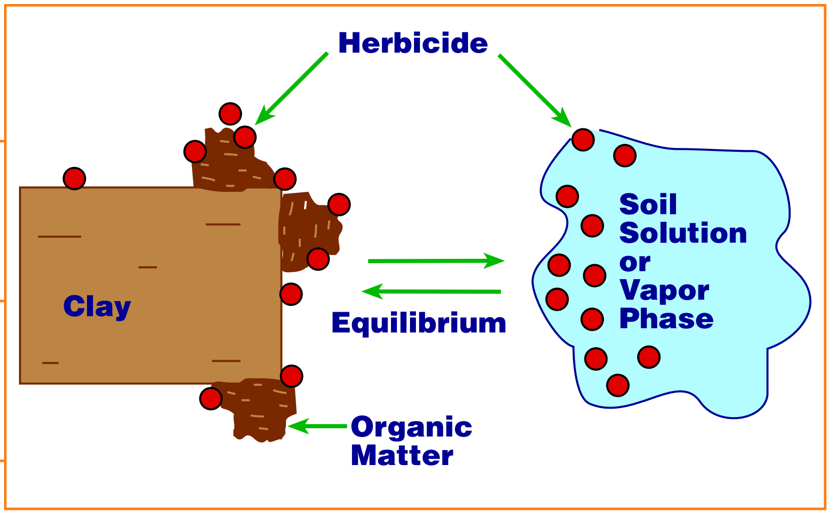


Figure 2. Adsorption is a term that describes a chemical's tendency to bind or 'stick' to soil particles.

How Atrazine is Lost from Crop Fields

The movement of atrazine from crop fields is determined by the chemical properties of atrazine; soil and site characteristics; tillage practices; and rainfall duration, intensity, and timing. When atrazine loss occurs, it begins in the top inch of soil, called the "mixing zone."

Chemical Characteristics of Atrazine

Each individual herbicide and herbicide chemical family has unique chemical characteristics that influence whether that herbicide could cause water quality problems. Atrazine is a member of the triazine family of herbicides. The most important chemical characteristics that affect atrazine runoff are adsorption and persistence. The solubility of atrazine is also important, but plays a lesser role. Adsorption is a term that describes a chemical's tendency to bind or "stick" to soil particles, primarily clay and organic matter. Some herbicides, such as Prowl or Treflan, are so tightly adsorbed by soil particles that they only leave the field with eroding soil particles and not with the runoff water. Atrazine, however, is weakly adsorbed. Atrazine and other weakly soil-adsorbed herbicides primarily leave the field in runoff water and not with the eroding soil particles. K-State researchers have found that approximately 90 percent of atrazine loss occurs in the water portion of runoff and only 10 percent with the eroding soil particles.

Persistence refers to how long it takes for a herbicide to degrade in the soil following application. The longer the herbicide lasts before degrading, the longer the period of weed control and the greater the opportunity for herbicide loss. Atrazine applied in April or May has a half-life of approximately 60 days, which means that by 60 days following application, half the atrazine will be broken down. **Atrazine's fairly long half-life, combined with its adsorption characteristics, are the major reasons why atrazine appears regularly in surface water samples collected in Kansas.**

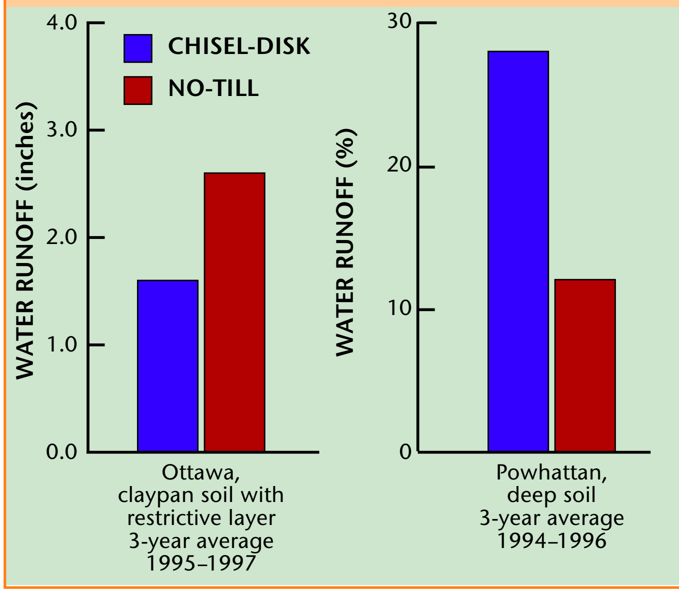
Soil and Site Characteristics

Soil and site characteristics are important factors when determining whether atrazine runoff will be a problem. Soils are categorized into four hydrologic groups — A, B, C, and D. Hydrologic soil groups are determined by estimating water intake at the end of a long-term storm, which occurs under wet conditions and with bare soil. Group A soils have high infiltration rates and low runoff potential. Group B soils have moderate infiltration and moderate runoff. Group C soils have slow infiltration and rapid runoff. Group D soils have very slow infiltration and very rapid runoff potential. Hydrologic soil group is an excellent indicator of a soil's potential to transport pesticides by either surface runoff or leaching. Identification of specific hydrologic soil groups is found in most modern NRCS soil surveys. Group D soils would be of most concern for atrazine runoff, followed by Group C soils. **In general, the greater the slope and the higher the clay content in the surface soil, the greater the atrazine runoff potential.**

Tillage Practices

Reducing tillage will reduce atrazine runoff on some soils, but could increase atrazine runoff on other soils, depending on soil characteristics and atrazine application methods and timing. K-State Research and Extension has examined the effects of adopting no-tillage compared to reduced-tillage or conventional-tillage at several locations and soils in Kansas. Results have been mixed (Figure 3). Atrazine runoff loss is directly correlated to: (1) the amount of water runoff from a field, and (2) atrazine application methods and timing. Generally, greater water runoff results in greater atrazine runoff loss when atrazine is not incorporated.

FIGURE 3. Effect of tillage on water runoff on shallow claypan and deeper soils.



At the East Central Experiment Field near Ottawa, preplant incorporation of atrazine in a chisel-disk system reduced atrazine loss in surface runoff by 76 percent compared to soil surface applications under a no-till system (Olson, et al., 1998). The Ottawa site has a somewhat poorly drained Woodson silt loam soil. Tillage variables were in place more than 5 years in this study.

A similar study in northeast Kansas near

Powhattan over a 3-year period conducted on a more permeable Grundy silty clay loam soil found 50 percent less season-long water runoff from a no-till system compared to a conventional disk tillage system. Atrazine runoff, however, was 59 percent higher in no-till than chisel-till due to application methods.

At both sites, atrazine was surface-applied on the no-till plots and incorporated in the tilled plots. This demonstrates the importance of application method and timing in atrazine runoff. To reduce atrazine runoff where it is surface applied, the atrazine should be applied early, when rainfall events tend to be less intense. **The rule of thumb is that regardless of tillage system, a series of atrazine best management practices is necessary to minimize atrazine runoff.**

Rainfall Duration, Intensity, and Timing

The surface soil moisture at time of herbicide application, length of time from herbicide application until first rainfall, and the intensity and duration of the first rainfall, greatly influence the amount of atrazine lost in surface runoff. The wetter the soil surface at the time atrazine is applied, the sooner runoff begins during a rain and the greater the potential for atrazine runoff. If the soil surface is dry at the start of a rainfall event, more water (and atrazine) infiltration will occur at the initially and less will be available for runoff. Rainfall that soaks into the soil prior to runoff will move some of the atrazine below the mixing zone, reducing the amount of atrazine subject to runoff losses. Generally, soil moisture levels are high in spring and early summer, the period of time when most of the atrazine is applied. Often, about two-thirds of the total atrazine runoff occurs with the first major storm/runoff event following application. The longer the interval between application time and first runoff event, the less atrazine runoff is expected.

The intensity, duration, and amount of the first rain is critical when considering potential atrazine runoff. The highest amount and intensity of rainfall, and the period of highest potential for runoff, occurs during the peak atrazine application period of May, June, and July (Figure 4). As rainfall intensity increases, the water runoff rate increases and so does the potential for atrazine loss. A gentle rain will move some of the atrazine below the soil surface and reduce the amount of atrazine available for runoff.

Atrazine runoff will be least when: (1) atrazine is applied to a dry soil surface; (2) at least 7 days occur between herbicide application and the first rain storm causing runoff; and (3) the first rain after application is of low intensity.

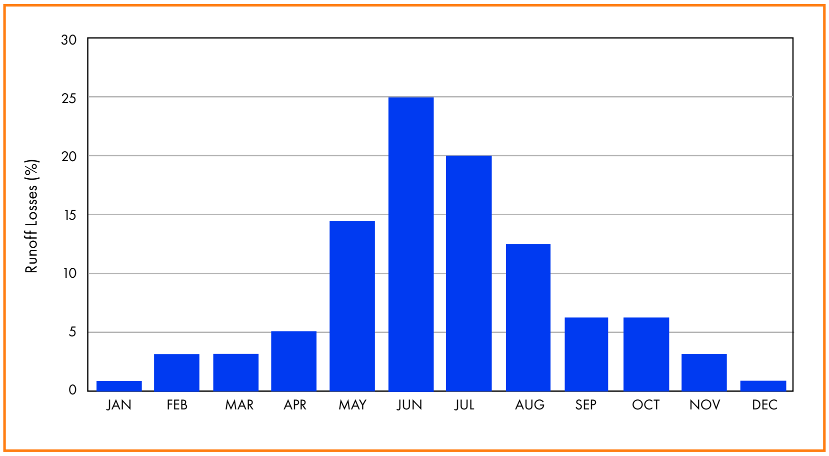


Figure 4. Average annual runoff and erosion losses in northeastern Kansas (percentage of annual total).

Atrazine Best Management Practices —Recommendations

K-State researchers have investigated atrazine runoff and found that annual atrazine runoff losses often range from 1 to 3 percent of the total applied. K-State researchers have also studied the effect of various management practices on atrazine runoff and have determined those best management practices (BMPs) which, when adopted by farmers, will minimize atrazine runoff. The BMPs that are listed in this publication are not suited for every field. Farmers should select the BMPs for their field that fit within their management system, are economical, and are most effective in reducing atrazine runoff.

Atrazine BMPs are designed to: (1) reduce the availability of atrazine for loss after application; (2) reduce the rate of atrazine used in a field/watershed; (3) reduce the impact of the first runoff event on atrazine loss; and (4) provide a mechanism for deposition of the atrazine before it leaves the field.

Recommended Atrazine Best Management Practices

1. Incorporate atrazine into the top 2 inches of soil

This is an excellent BMP for fields where tillage is used prior to planting corn or grain sorghum. Apply preplant atrazine alone or as part of a tankmix and incorporate it into the top 2 inches of soil with a field cultivator, tandem disc, or other appropriate tillage implement. Avoid deep incorporation, which will reduce weed control. Incorporation will reduce the amount of atrazine in the mixing zone of the soil, where it is most vulnerable to runoff. Incorporation will reduce atrazine runoff by **60 to 75 percent** compared to a surface application without incorporation. Incorporation will improve weed control if rainfall does not occur within seven days of herbicide application.

***Caution**: This BMP should be used only if tillage is already planned and the atrazine incorporation can be part of a planned tillage operation. Using tillage unnecessarily can lead to increased soil erosion and soil loss to surface water. Suspended solids (sediment) in Kansas surface waters is considered to be a major environmental concern.*

2. Use fall or early spring applications

Atrazine runoff can be reduced by **50 percent** by applying atrazine the previous fall (between fall harvest and December 31) or prior to April 15 of the current cropping year. Rainfall intensity, duration, and amount is typically lower during fall and winter than in late April, May, and June, resulting in less water and atrazine runoff. This is a good BMP for no-till fields where preplant incorporation and certain other BMPs may not be appropriate. Rainfall events in late fall, winter, and early spring are normally of lower intensity, allowing the atrazine to be moved into the soil (and out of the mixing zone) prior to runoff occurring. The fall atrazine

K-State Research Results

At the Cornbelt Experiment Field in Brown County, atrazine runoff in a disk tillage system in which atrazine was preplant incorporated was 62 percent lower than a no-till system in which the atrazine was surface applied without incorporation. This was in spite of the fact that 50 percent less water runoff occurred in the no-till system compared to the disk tillage system.

A study conducted at the East Central Experiment Field in Franklin County with a grain sorghum - soybean rotation found 70 to 82 percent reductions in atrazine runoff when atrazine was preplant incorporated compared to atrazine applications that were applied preemergence and not incorporated.

application will also control winter annual weeds, and will eliminate or reduce the need for burndown herbicides in no-till, or reduce the number of tillage operations necessary prior to planting. K-State recommends that fall atrazine applications be made on fields that will be no-tilled with more than 30 percent crop residues present. Under no-till conditions, a fall atrazine application will need to be followed by a soil-applied treatment at planting time or a postemergence herbicide application for season-long control. ***Caution****: Atrazine must not be applied to frozen soils. The drier the soil surface, the more atrazine that will be adsorbed before the first major storm/runoff event occurs. Applications to wet soil surfaces increase atrazine runoff potential. Fall and early spring applications may require another herbicide application at planting time or postemergence. Higher total rates will be needed when applying atrazine in the fall or early spring, which will increase weed control costs. Higher-than-normal winter and spring precipitation may dilute the atrazine and result in poor weed control.*

3. Use postemergence atrazine premix products

Postemergence herbicide products that contain low rates of atrazine in mixtures with other herbicides are widely used by Kansas farmers. The postemergence products typically contain atrazine at rates of 0.5 pounds per acre, which is approximately 60 to 70 percent lower than typical soil-applied atrazine application rates. In addition, the growing crop foliage helps reduce atrazine runoff potential by intercepting some of the atrazine and reducing the impact of the storm at the soil surface. When using postemergence products with grain sorghum, which is planted later than corn, application can be delayed until late June or early July

TABLE 2. Postemergence Herbicide Premix	Amount of Atrazine (lbs./acre) at Normal Use Rate
Buctril & Atrazine	0.5
Marksman	0.5
Laddok S-12	0.5
Shotgun	0.5
Contour	0.5
Basis Gold	0.75

when the soil surface can be expected to be drier. Using postemergence applications results in **50 to 67 percent** less atrazine runoff compared to typical preemergence soil-applied atrazine applications. In addition, when using a postemergence product, the herbicide mixture/treatment can be based on the specific weed species and weed populations present. K-State research has found that postemergence products containing atrazine provide better control than preemergence soil-applied atrazine of tough, large-seeded broadleaf weeds such as velvetleaf, common cocklebur, and common sunflower. ***Caution**: Postemergence applications containing atrazine and other herbicides are generally more expensive on a per-acre basis, and require an additional application trip across the field. In addition, wet soil conditions may prevent timely postemergence application and lead to reduced grain yields.*

4. Reduce soil-applied atrazine application rates

There is a direct relationship between atrazine application rate and runoff amount. The lower the rate applied, the less the potential atrazine runoff. Using lower atrazine rates, and/or formulations with lower atrazine rates, can still provide excellent control of pigweed and other small-seeded broadleaf weeds. Mixtures of atrazine and an acid amide herbicide, such as Dual Magnum, Lasso, Harness, Frontier, or Surpass often provide excellent pigweed and annual grass control. "Lite" formulations that contain less atrazine can reduce atrazine runoff potentially by **33 percent**. ***Caution**: If atrazine is the primary broadleaf herbicide used, reducing atrazine rates may lead to unsatisfactory weed control, particularly for large-seeded broadleaf weeds, such as velvetleaf, common cocklebur, and common sunflower. Supplemental herbicides or weed management strategies may be needed to control escaped weeds.*

TABLE 3. Soil-applied Herbicide Premix	Amount of Atrazine (lbs./acre) at Normal Use Rate
Bicep II Magnum	1.6
Bicep Lite II Magnum	1.0
Harness Xtra 5.6	1.5
Guardsman	1.2
FulTime	1.2
Ramrod/Atrazine	1.3
Lariat/Bullet	1.5

5. Use split applications of atrazine

Apply atrazine and tankmixes as split applications. For example, apply one-half to two-thirds of the atrazine prior to April 15 and one-third to one-half just prior to or immediately following planting. Using split applications reduces the amount of atrazine available for runoff at any one time. In addition, the early application is made at a less vulnerable time for atrazine runoff. This BMP has the potential to reduce atrazine runoff by **25 percent** compared to applying all the atrazine at planting time. ***Caution**: Weed control costs may be increased, but only if two application trips across the field are required instead of one.*

6. Use reduced soil-applied atrazine rates followed by a postemergence herbicide application

Applying atrazine at a reduced soil-applied rate of approximately 1 pound per acre at planting time followed by a postemergence application of a premix product that contains low rates of atrazine results in **25 percent** less atrazine runoff compared to surface applying all atrazine at planting time, while generally providing excellent broadleaf weed control. This BMP reduces the amount of atrazine applied at planting time. This two-step approach of using preemergence atrazine followed by a postemergence premix product has consistently resulted in the best weed control over a broad spectrum of broadleaf and grass weeds in corn and grain sorghum. This program may be less costly on a per-acre basis if the initial application provides needed weed control and the postemergence application is not necessary. ***Caution****: Herbicide costs are higher for the two-step program — both in higher herbicide costs and the two application trips across the field. Wet field conditions may prevent timely postemergence application and reduce weed control.*

TABLE 4.

Non-atrazine Herbicide	Types of Weeds Controlled
Lightning	Broadleaf Many grasses
Hornet	Broadleaf
Exceed	Broadleaf Shattercane Johnsongrass
Balance	Broadleaf Many grasses
Roundup Ultra	Broad spectrum
Liberty	Broad spectrum

7. Use non-atrazine herbicides

New herbicides that do not contain atrazine are available for use in corn and grain sorghum. For corn, herbicide programs are available that include little or no atrazine. These include Lightning for use on Clearfield (IMI) corn, Liberty for use on Liberty Link corn, and Roundup Ultra for use on Roundup Ready corn. Non-atrazine herbicides available for conventional corn include Balance, Hornet, and Exceed. Balance herbicide controls a weed spectrum very similar to that of atrazine, and works best when substituted for one-half to two-thirds of the planting time rate of atrazine. Hornet helps control many large-seeded broadleaf weeds. Exceed controls shattercane, Johnsongrass, and many broadleaf weeds. Using non-atrazine alternatives reduces atrazine runoff by up to **100 percent.** ***Caution****: Alternative herbicides also may be lost in runoff unless improved management practices are also implemented.*

8. Use integrated pest management strategies

Integrated pest management strategies combine prevention, suppression, monitoring, and pesticides to control weeds while minimizing the amount of herbicide needed. Crop rotation; preplant tillage; in-season cultivation; hand-roguing; changes in row spacing, planting date, or seeding rate; crop scouting; cover crops; variety/hybrid selection; and spot herbicide treatments can reduce weed infestations, improve the crop's ability to compete with weeds, and reduce the amount of herbicide needed. This program can reduce atrazine runoff by **0 to 100 percent**. ***Caution****: Weed infestation levels should be known before reducing herbicide rates.*

9. Band herbicides at planting or cultivation

Banding the atrazine application over the row as a 10- to 15-inch band reduces the total amount of atrazine applied to a field by **50 to 67 percent**, resulting in a corresponding reduction in atrazine runoff compared to a broadcast surface application without incorporation. Banding also reduces herbicide costs. Weeds in the untreated middle of the rows will be removed by in-season cultivation. This system works particularly well for ridge tillage and other situations where cultivation will be used. ***Caution****: Cultivation may increase soil erosion and moisture loss. Wet conditions may prevent timely cultivation and lead to weed escapes and yield losses.*

10. Establish vegetative and riparian buffer areas

Vegetative and riparian buffer areas include grass waterways, field boundaries, and areas along streams and ponds. These buffers are effective at slowing down runoff and collecting soil particles from erosion. Vegetative and riparian buffers may reduce the amount of water runoff by increasing infiltration of runoff water within the buffer. To the extent that water infiltrates into the buffer strip soils, atrazine loss will also be reduced. Vegetative buffers are most effective at reducing water (and atrazine) runoff if the water is spread out evenly as it flows across the filter. If water infiltration in the buffer area does not occur, atrazine runoff will not be reduced as the vegetation itself will not adsorb atrazine. Many grass waterways concentrate runoff and so are not highly effective for reducing atrazine runoff. Vegetative and riparian buffer areas can reduce atrazine runoff by **10 to 35 percent**. ***Caution****: Vegetative and riparian buffer areas must have even water flow across the buffer to be effective.*

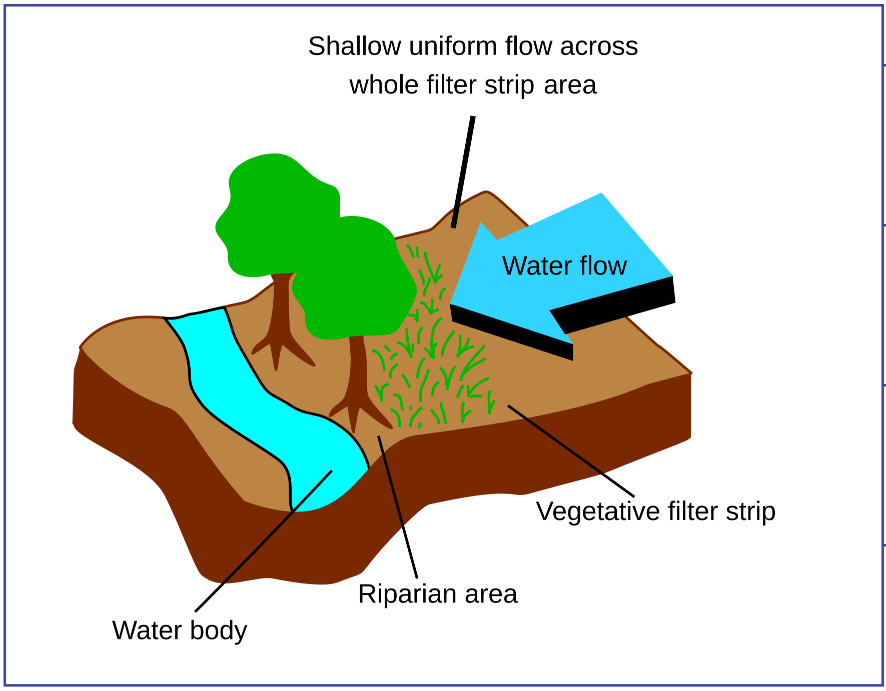


Figure 5. Vegetative filter strips are most effective if water spreads out evenly as it flows across the filter.

11. Use proper atrazine rates, mixing, loading, and disposal practices

It is important that all label requirements be followed when using atrazine and other pesticides. The rate should be chosen carefully and tailored to label recommendations, water quality concerns, weed infestations, soil type, etc. Using above-labeled atrazine rates is unlawful and may lead to increased atrazine runoff, crop damage, and carryover concerns. All application equipment should be calibrated regularly to maintain accuracy of application. All pesticides should be stored in appropriate storage facilities.

Be careful when mixing and loading the spray tank with atrazine and other herbicides. Mix and load in the field and away from wells and surface water. Loading from a nursetank is preferable to loading directly from a well. If loading from a well, a backflow device should be used to prevent back-siphoning into the well. Follow product label recommendations on rinsing and disposing of the herbicide container. Spray-rinse water should be applied back onto the target field and not drained near wells, ponds, lakes, or streams.

12. Utilize conservation practices and structures

Conservation practices and structures that slow or reduce water runoff and soil erosion from a field will reduce atrazine runoff. Most conservation practices and structures reduce soil erosion more than water runoff. Conservation practices and structures that primarily reduce soil erosion may have little impact on atrazine runoff, as the majority (more than 90 percent) of atrazine loss occurs in runoff water.

■ *Reduced and no-tillage*

Adopting reduced and no-tillage systems will reduce sediment loss from a field by up to 90 percent and will likewise reduce sediment-bound atrazine. Atrazine contained in the water portion of runoff may or may not be reduced, depending upon soil type, surface soil moisture level, land use, slope, and application method and timing. Generally, K-State research has found that atrazine runoff is lower in reduced-tillage where atrazine is incorporated, than in no-tillage systems where atrazine is surface applied. Adopting one of the application timing BMPs above can help reduce atrazine runoff in no-till where surface applications are made. Although no-till can result in increased atrazine runoff under some conditions, no-till has many environmental benefits, such as reducing soil erosion.

■ *Water and sediment control basins*

Water and sediment control basins slow down and store water and trap soil particles from erosion. Basins are especially effective at reducing soil-bound atrazine losses, and can be effective at reducing atrazine losses in runoff water. Basins are most effective when they store water until soil infiltration or evaporation occurs. However, in many basins there is an outlet, similar to a tile outlet terrace system, that releases water. With a release outlet, the basin is not very effective in preventing atrazine movement into streams.

■ *Contour farming*

Field and planting operations performed at or nearly perpendicular to the slope of the land results in decreased sheet and rill erosion (along with soil-adsorbed atrazine) by creating furrows or small dams perpendicular to the slope. Contour farming also increases the time between onset of rainfall and initiation of runoff, which allows time for some of the atrazine to be moved below the mixing zone and reduces atrazine runoff.

■ *Gradient terraces*

Gradient terraces are designed to reduce the slope length, erosion, and soil content in runoff water. These terraces are designed to divert runoff to a suitable outlet, such as a grassed waterway. Gradient terraces reduce soil erosion (and subsequent soil-bound atrazine). They also may result in a slight reduction in water runoff (and atrazine in runoff water) from the field by increasing infiltration in the terrace channel. The atrazine concentration contained in the runoff water can be further reduced in the grassed waterway if the water flow is evenly distributed across the waterway.

■ *Tile outlet terraces*

Tile outlet terraces are similar to gradient terraces except that water collected in the terrace is diverted from the field through an underground tile outlet. Tile outlet terraces do an excellent job of reducing soil erosion. However, only a slight reduction occurs in water runoff. Tile outlets that empty directly into a roadside ditch or stream may actually result in increased atrazine losses into surface water. Moving tile outlets back away from surface waterways and spreading out the discharge from the tile outlets across a grass buffer may reduce atrazine runoff losses to surface water.

Summary

Atrazine is used widely in Kansas for weed control in corn and grain sorghum. The herbicide provides cost-effective weed control and has wide application flexibility. In recent years there have been concerns about the levels of atrazine moving from corn and grain sorghum fields into surface waters. The highest levels of atrazine in surface water occur in the spring and summer months following herbicide application. The movement of atrazine from crop fields is determined by the chemical properties of atrazine; soil and site characteristics; tillage practices; application timing and methods; and rainfall duration, intensity, and timing. K-State researchers have studied the effect of various management practices on atrazine runoff and have determined those BMPs which, when adopted by farmers, will minimize atrazine runoff. The greatest reduction will be achieved by using a combination of BMPs. Farmers are encouraged to adopt the BMPs for their fields that are most economical and most effective in reducing atrazine runoff. Atrazine BMPs are designed to: (1) reduce the availability of atrazine for loss; (2) reduce the rate of atrazine used in a field/watershed; (3) reduce the impact of the first runoff event; and (4) provide a mechanism for deposition of the atrazine before it leaves the field.

12 Best Management Practices for Atrazine

1. Incorporate atrazine into the top 2 inches of soil
2. Use fall or early spring applications
3. Use postemergence atrazine premix products
4. Reduce soil-applied atrazine application rates
5. Use split applications of atrazine
6. Use reduced soil-applied atrazine rates followed by a postemergence herbicide application
7. Use non-atrazine herbicides
8. Use integrated pest management strategies
9. Band herbicides at planting or cultivation
10. Establish vegetative and riparian buffer areas
11. Use proper atrazine rates, mixing, loading, and disposal practices
12. Utilize conservation practices and structures

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Kansas State University Agricultural Experiment Station and Cooperative Extension Service

MF2208 February 2000