Understanding and reducing pesticide losses

A small portion of pesticides applied on farms inadvertently reaches surface and groundwater. The amount varies from nearly zero to sometimes more than 5 percent of the amount applied, depending on several factors discussed below. That may not seem like much, but a 1 percent loss of a l-pound-per-acre pesticide application can contaminate all of the drainage from a field in a normal year at 5 parts per billion (ppb). This level can be of concern if the drainage water enters drinking water supplies. The U.S. Environmental Protection Agency has established health advisory levels (HALS) for most pesticides in drinking water. Health advisory levels are guides to the level of chronic exposure of an individual to pesticides.

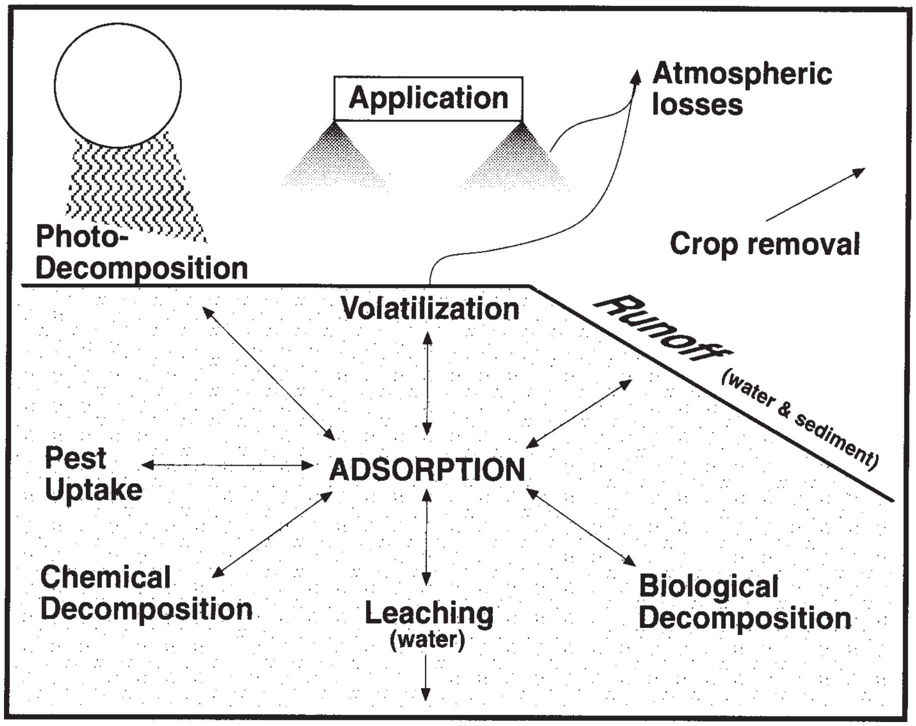

Figure 1. Pesticide fates.

Impacts of pesticide losses

Economically, losses may not be significant, but they are quantifiable and of concern with some chemicals. For example, atrazine has been detected in water supplies and in private and public drinking water sources.

An estimated 340 tons of atrazine, or 1.2 percent of that applied in the 12 states that drain into the Mississippi River, flowed into the Gulf of Mexico from April 1991 to March 1992, based on U.S. Geological Survey water tests. Three-quarters of that loss occurred in April, May, and June, when the median atrazine concentration was 1.1 ppb.

Atrazine was detected in 4.4 percent of the samples from water supply wells tested in Iowa during 1988 and 1989, with 0.7 percent exceeding the drinking water standard for the herbicide. Overall, water samples were tested for 27 commonly used pesticides with 13.6 percent of the samples found to contain one or more pesticides.

After atrazine, the commonly used herbicides Sencor/Lexone, Prowl, Dual, Bladex, and Lasso were most likely to be detected (ranging from 1.2 to 1.9 percent). Of the 27 pesticides, 16 were not found

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at detectable levels. Shallow wells, those less than 50 feet deep, were more likely to be contaminated (17.9 percent) than deeper wells (11.9 percent). Some detections result from accidents, point-source contamination, and poor well construction as well as general use and handling, but the study indicates the potential pollution of drinking water with pesticides.

How pesticides move

Agricultural scientists have spent years charting pesticide "pathways" to surface water and groundwater. In studies using real and artificial rain, researchers have discovered what happens to pesticides from the time they leave the application equipment. Knowing the routes chemicals take off the field helps in finding ways to reduce the losses.

The amount of chemicals that escape from the field, other than to the atmosphere, can be expressed in the following equation: **Losses = carriers × concentrations**. The carriers are represented by surface runoff water, sediment, and water leaching through the root zone (Figure 1). Losses can be reduced by decreasing the volume of the carriers or the pesticide concentration in the carrier or carriers.

For example, decreasing the carrier, such as by minimizing the amount of runoff through conservation practices, would reduce runoff losses. Reducing pesticide concentration, such as by banding to reduce the amount applied, would have a similar effect.

Several assumptions can be made about the potential losses of pesticides depending on their chemical properties. As discussed on pages 5 and 6, proper tillage and application practices can help reduce pesticide losses. Other practices can sometimes eliminate the need for pesticides.

Pesticide properties

Four properties largely determine the tendency of pesticides to move from the application site. The most important of the properties are persistence, soil adsorption, and vapor pressure. Solubility also is involved, but to a lesser extent than the others.

Persistence

Persistence is a pesticide's resistance to decompose through chemical, photochemical (sunlight), and microbial action. It is often expressed in terms of half-life, or the time it takes for 50 percent of the pesticide to break down. Table 1 and Figure 2 include the estimated half lives of some common pesticides.

Pesticides that persist longer in the environment are more likely to move off-site than less persistent ones because they remain in their original form longer. The metabolites, or decomposition products, of some pesticides retain their pesticidal properties and may remain toxic.

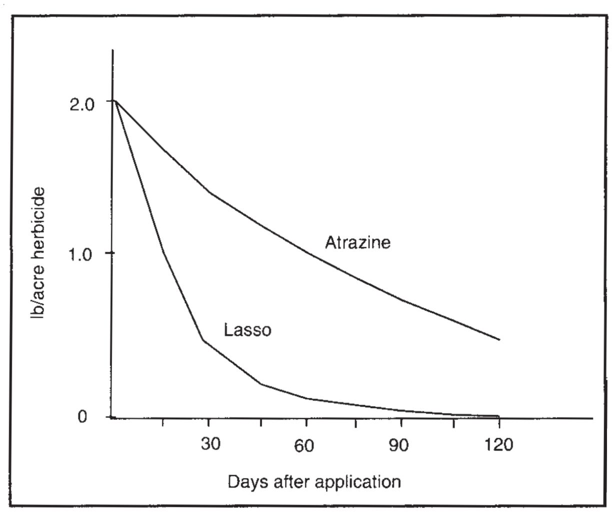

Figure 2. Half-lives of Lasso and Atrazine.

DDT and Dieldrin, two very persistent insecticides, have been detected throughout the world, including in Antarctica. They were banned largely because of their persistence; they have half-lives measured in years. Similarly, atrazine, because it is one of the more persistent and widely used herbicides, is more likely to be found in both surface water and groundwater.

Table 1. Properties of some common pesticides at 20–25˚C (68–77˚F)

Pesticide	Soil adsorption (K)*	Est. half-life (days)	Vapor pressure (Lasso=1)**	Solubility (mg/L)+	Health Advisory (µg/L)+
Herbicides					
Atrazine	2.0	60	0.021	33	3
Bladex	3.8	14	0.00011	170	1
Dual	4.0	90	2.2	530	100
Lasso	3.4	15	1	240	0.4
Lexone/Sencor	1.2	40	less than 1	1,220	10
Paraquat	20,000	1,000	0	620,000	30
Pursuit	0.2	90	NE	1,400	NE
Ramrod	1.6	6	16	613	90
Treflan	160	60	7.9	0.3	2
2,4-D	0.4	10	0.57	890	70
Insecticides					
Counter	10	5	23	5	1
Furadan	0.4	50	0.043	351	40
Lorsban	121	30	1.2	0.4	20
Dyfonate	17.4	40	24	17	10
Thimet	20	60	46	22	NE

* K, concentration in soil/concentration in water, for soil with 2% organic carbon
** Vapor pressure relative to that of Lasso (arbitrarily chosen as a reference point).
\+ mg/L, parts per million; µg/L, parts per billion (or 0.001 parts per million).
NE, not established.

Adsorption

Pesticide spray that lands on the ground binds to the soil in varying degrees, in a process called adsorption, but some pesticides adhere to soil more strongly than others (Table 1).

The amount of soil adsorption determines to a great degree the pesticide's route of loss. Pesticides that are strongly adsorbed are lost mostly with sediment. Those weakly to moderately adsorbed are lost mainly in surface runoff water. Many pesticides developed since 1960 are only moderately adsorbed, so erosion control has only a limited effect on their losses.

Vapor pressure

A pesticide's vapor pressure is a measure of its tendency to evaporate or become a gas. Application losses of sprayed pesticides to the atmosphere can be significant; losses of 50 percent or higher have been measured for pesticides applied on windy days.

In addition to vapor pressure, wind speed, temperature, and humidity combine with equipment operation, which affects spray droplet size, to determine the exact amounts of loss (Table 1).

Evaporation can continue after application. It affects postapplication losses to the atmosphere, especially for pesticides applied to crop residue where evaporation, or volatilization, may be a significant pathway of loss.

In an Iowa State University study, about 5 percent of the herbicide propachlor (commonly known as Bexton or Ramrod) escaped into the air in the first 24 hours after application. In the same period, less than 1 percent of the applied cyanazine (commonly known as Bladex) evaporated, largely because its vapor pressure is 140,000 times less than that of propachlor. Application and postapplication losses to the atmosphere may far exceed those moving with water.

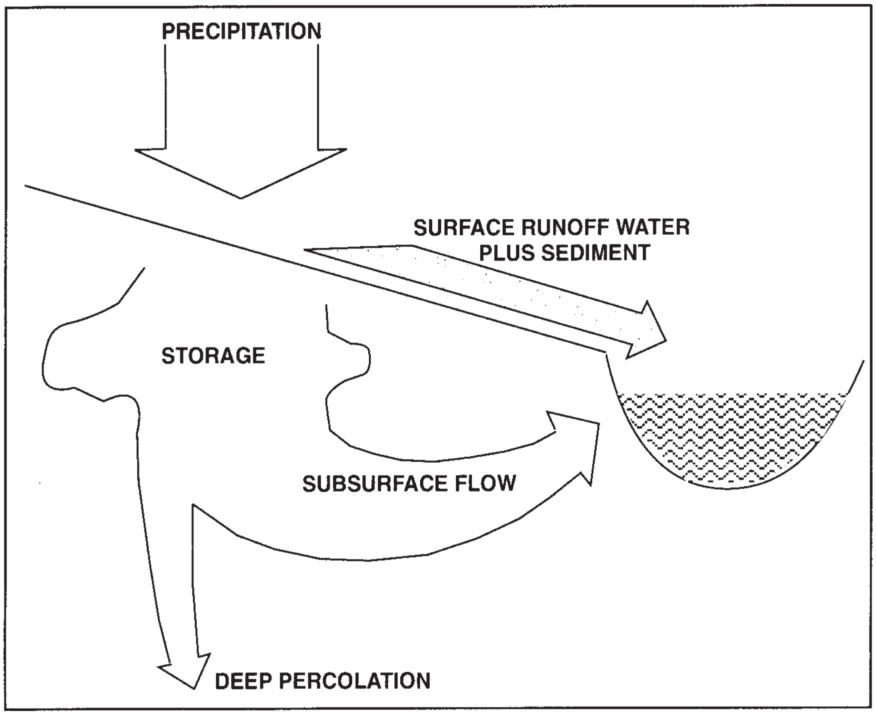

Figure 3. Hydrologic cycle.

What happens to pesticides lost to the atmosphere is not completely understood, but one fate is returning to the earth with precipitation. For example, an Iowa Department of Natural Resources study of pesticides in spring rainwater commonly detected alachlor and atrazine in concentrations approaching 1 ppb.

Runoff

Water is all that is necessary to separate pesticides from soil. Rainfall affects pesticides in two basic ways: either by breaking their bond with the soil and dissolving them in water or by loosening and transporting pesticide-laden soil particles through erosion. Both mechanisms threaten pollution of water resources.

Surface runoff contains the highest concentration and greatest losses of pesticides in the first runoff event after application. Losses in surface runoff almost always are less that 5 percent of that applied. However, surface runoff usually far exceeds the losses (and therefore the concentrations) for subsurface drainage and percolation, which are typically in the range of 0.01 to 0.5 percent (Figure 3).

The rate and route of water infiltration into soil to a large extent determine pesticide concentrations and losses in surface runoff. The timing of the rainfall after application also has an effect. Studies show that rainfall interacts with chemicals in a shallow depth of soil, about 1/4 to 1/2 inch, called the mixing zone (Figure 4). The pesticide concentration in initial runoff water decreases the longer it takes for runoff to begin during a rainstorm.

Leaching of the pesticide from the mixing zone during a rainstorm decreases concentrations, both in the initial runoff and during the runoff event.

The amount of initial infiltration of rain before runoff begins is essential in determining pesticide concentrations and losses. For example, compaction, which causes more runoff to occur sooner, increases both concentrations and losses.

Leaching

Uncultivated, no-till farming will cause an increase in the number of soil aggregates, or groups of soil particles and organic matter, and their stability in the soil. This structural combination of soil particles and organic matter is a natural process of soil development. No-till farming provides an enhanced environment for biological activities to occur in the soil. The spaces between individual aggregates are open channels, often termed macropores.

Some macropores are continuous from the soil surface to below the rooting zone. Other macropores may extend to a shallow depth within the soil profile. No-till farming may result in open channels at the ground surface. With tillage, these openings are destroyed roughly in proportion to the severity of soil disturbance. These channels may either increase or decrease pesticide leaching, depending on the position of chemicals relative to water movement through these preferential flow paths, or macropores. For example, if pesticides are applied on the surface and an intense storm produces saturated soil or ponding, chemical leaching through the macropores would tend to increase. In contrast, if the rainfall was gentler and soaked in before ponding, pesticide-laden water within aggregates would generally be bypassed by water flowing in the macropores, decreasing the leaching potential.

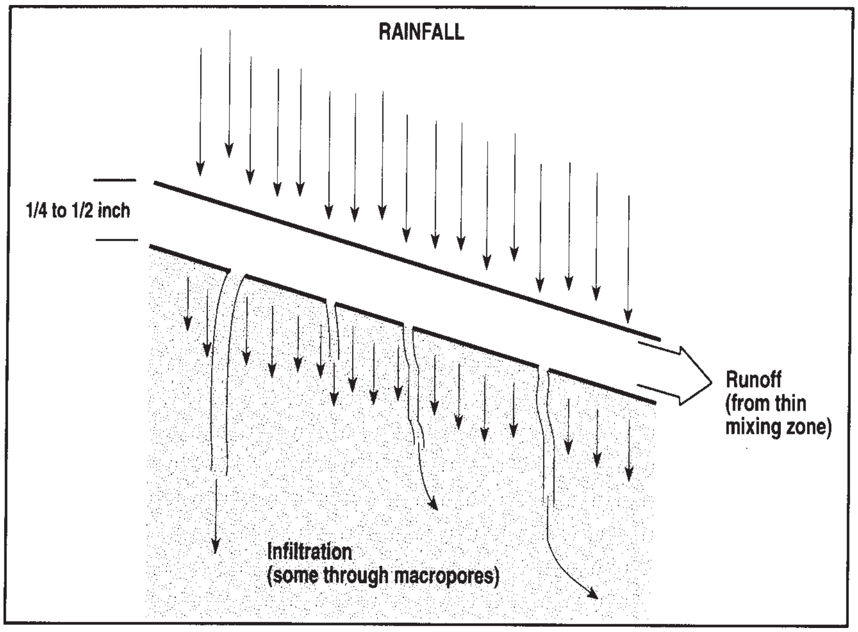

Figure 4. Rainfall infiltration.

Reducing pesticide losses

Tillage practices

The way ground is tilled plays a significant role in the potential loss of pesticides. Reduced tillage includes both advantages and disadvantages when it comes to reducing pesticides in runoff. Reduced or conservation tillage, which has been shown to decrease runoff and erosion, has some potential to reduce pesticide runoff losses. For example, an Iowa State University study found that ridge tillage reduced runoff 35 percent, erosion 62 percent, and alachlor (Lasso) loss 52 percent.

In addition to decreasing erosion, crop residue has a beneficial effect on infiltration. In a study of herbicide runoff losses, 1,350 pounds per acre of residue delayed surface runoff by 18 minutes compared with soil that had no residue cover. In addition, the amount of runoff was reduced by 72 percent. The combined effects of delayed and reduced runoff resulted in an 83 percent decline in atrazine losses.

More crop residue on the soil surface, however, increases the possibility of spray interception and subsequent pesticide wash-off and volatilization because of little pesticide interaction with the residue compared with soil adsorption. Some studies suggest that as much as 50 percent of some pesticides is washed off the residue by a light, 1/2-inch rain.

If wash-off becomes part of surface runoff rather than soaking into the soil, pesticide concentrations with conservation tillage may exceed those where pesticides are directly applied to bare soil.

Soil incorporation reduces the amount of pesticide left on the soil surface. This practice minimizes the pesticide exposure both to wind and rain, an important way to avoid losses. Reduced tillage is to some degree in conflict with soil incorporation.

Application practices

The different ways pesticides are applied affect the potential of their loss in surface runoff and subsurface drainage.

Pesticide concentrations and losses in both surface runoff and subsurface drainage water are nearly proportional to the amount applied. Reducing the amount applied should reduce concentrations and losses. Because soil adsorption is slightly stronger at lower concentrations of the pesticide in the soil, water concentrations and losses should decline even more than the reduction in the application rate.

Reducing the rate of pesticide application is usually the most effective way to lower pesticide concentration and losses to water resources. Practices such as banding, which reduce the area and therefore the rate of application, should decrease pesticide concentrations and losses. Keeping application equipment properly calibrated is important to accurately control the amount of pesticide applied.

Soil incorporation can significantly reduce surface runoff losses of pesticides and also losses to the air by decreasing the amount in the shallow surface soil, or mixing zone. Several pesticides also provide increased pest control when incorporated.

Timing of application is another way to prevent pesticide losses. Intense storms tend to occur in Iowa during May and June. If feasible, planning applications for other than those months could avert conditions favorable for increased pesticide losses. Because losses to the atmosphere are increased by wind, it is advisable to delay spraying until the wind is calmer, such as in the early morning or evening.

Pesticide selection

Picking pesticides that are less persistent, more strongly adsorbed, and of lower volatility also would control losses of pesticides from fields, either to the atmosphere or in water. As information becomes available on new formulations, for example, starch-encapsulated ones, there may be additional options to reduce losses. Granular formulations, although not always feasible, can reduce application losses to the atmosphere.

Cultural practices

If possible, determine thresholds of pests before resorting to chemical methods of control. Expense and environmental damage from pesticide applications could be prevented if weed or insect infestations are below the economic effect level.

Crop rotation tends to reduce the need for pesticides, thereby eliminating or reducing their use. For example, corn following soybeans usually does not require rootworm insecticides.

Strip-cropping can be used to slow sediment and runoff movement by interrupting the flow of water from a field. Contour buffer strips also tend to decrease pesticide losses by reducing the movement of eroded sediment. Producers should consider these practices for vulnerable areas, such as sinkholes and drainage ways, when applying pesticides. Management practices should be implemented in these areas to prevent pesticide losses.

Prepared by James Baker, professor of agricultural and biosystems engineering; and Gerald Miller, professor of agronomy. Edited by Julie Todd, extension program specialist.

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