4B: Pesticide Management

Management Measure for Pesticides

To reduce contamination of ground and surface water from pesticides:

1. Inventory pest problems, previous pest control measures, and cropping history.
2. Evaluate the soil and physical characteristics of the site including mixing, loading, and storage areas for potential leaching or runoff of pesticides. If leaching or runoff is found to occur, steps should be taken to prevent further contamination.
3. Use integrated pest management (IPM) strategies that
   - ❐ apply pesticides only when an economic benefit to the producer will be achieved (i.e., applications based on economic thresholds) and
   - ❐ apply pesticides efficiently and at times when runoff losses are least likely.
4. When pesticide applications are necessary and a choice of registered materials exists, consider the persistence, toxicity, runoff potential, and leaching potential of products in making a selection.
5. Periodically calibrate pesticide application equipment.
6. Use anti-backflow devices on the water supply hose, and other safe mixing and loading practices such as a solid pad for mixing and loading, and various new technologies for reducing mixing and loading risks.

Six general principles guide safe pesticide management.

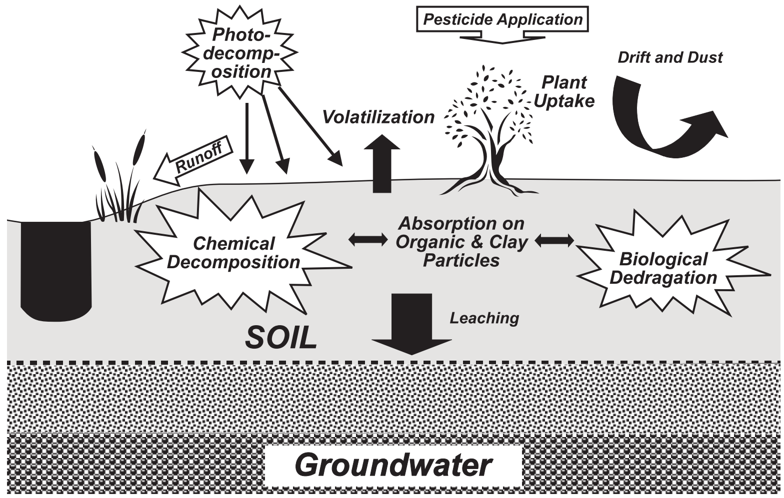
Management Measure for Pesticides: Description

The goal of this management measure is to reduce contamination of ground and surface water from pesticides. The basic concept of the pesticide management measure is to foster effective and safe use of pesticides without causing degradation to the environment. The most effective approach to reducing pesticide pollution of waters is, first, to release a lesser quantity of and/or less toxic pesticides into the environment and, second, to use practices that minimize the movement of pesticides to ground and surface water (Figure 4b-1). In addition, pesticides should be applied only when an economic benefit to the producer will be achieved. This usually results in some reduction in the amount of pesticides being applied to the land, plants, or animals, thereby enhancing the protection of water quality and possibly reducing production costs as well.

Pesticide management consistent with this management measure is based on pesticide application only when an economic benefit is anticipated.

The pesticide management measure identifies a series of steps or thought processes that producers should use in managing pesticides. First, the pest problems, previous pest control measures, and cropping history should be evaluated for pesticide use and water contamination potential. Second, the physical characteristics of the soil and the site, including mixing, loading, and storage areas, should be evaluated for leaching and/or runoff potential. Integrated pest management (IPM) strategies should be used to minimize the amount of pesticides applied. In rare cases, IPM practices may not be available for some

Figure 4b-1. Pesticide Fate: Major Pathways



commodities or in certain regions. An effective IPM strategy should call for pesticide applications only when an economic benefit to the producer will be achieved and not on a routine schedule. In addition, pesticides should be applied efficiently and at times when runoff and leaching losses are unlikely.

Pesticide labels must be followed.

When pesticide applications are necessary and a choice of materials exists, producers are encouraged to choose the most environmentally benign pesticide products. State Cooperative Extension Service specialists and Natural Resources Conservation Service field staff may be able to assist producers in this selection process.

Users must apply pesticides in accordance with the requirements on the label of each pesticide product. Label instructions include the following: allowable use rates; whether the pesticide is classified as “restricted use” for application only by certified and trained applicators; safe handling, storage, and disposal requirements.

At a minimum, effective pest management requires evaluating past and current pest problems and cropping history; evaluating the physical characteristics of the site; applying pesticides only when an economic benefit to the producer will be achieved; applying pesticides efficiently and at times when runoff losses are unlikely; selecting pesticides (when a choice exists) that are the most environmentally benign; using anti-backflow devices on hoses used for filling tank mixtures and on chemigation systems; and providing suitable mixing, loading, and storage areas. Other factors which may influence pesticide management decisions include long-term pest management, resistance management, nutrient management, and soil conservation.

Calibrating equipment saves money and reduces damage to the environment.

Pest management practices should be updated whenever the crop rotation is changed, pest problems change, or the type of pesticide used is changed. Application equipment should be calibrated and inspected for wear and damage frequently and repaired when necessary. Anti-backflow devices should also be inspected and repaired on a regular basis.

Pesticides: An Overview

What are pesticides?

Agricultural pesticides are chemicals which are used to protect crops against damaging organisms. They are generally divided into four categories according to the target pests:

Insecticides are targeted at insect pests. There are many kinds of insecticides in use today. They may be applied to the soil to protect roots, seeds, or seedlings. They may also be applied to the crop to protect stems, leaves, or fruit. Some of the most common insecticides include chlorpyrifos, diazinon, and carbaryl. Many insecticides kill the insects by disrupting their nervous system, resulting in paralysis and death. Unfortunately, they can have the same effect on non-target insects or fish and animals if enough of the applied product drifts or washes from the field.

Herbicides are used to control weeds in crops. Up to 80% of all pesticides sold are herbicides and they are used in most crop production systems. Weed control is one of the most effective practices to increase yields. Herbicides can be selective, killing the weeds but not the crop, such as atrazine in corn or trifluralin in soybeans. Other herbicides, such as glyphosate or paraquat, are non-selective, killing all plants they contact except those genetically engineered to be resistant to that particular herbicide or those that have developed resistance due to selection by the herbicide. Many herbicides have relatively low toxicity to insects, fish, or animals because they target specific enzyme systems found only in plants (Stevens and Sumner, 1991). This is particularly true for newer herbicides.

Fungicides are used to control fungi which cause disease in crops. They are applied to seeds, to soil, or to the crop to prevent or slow disease when conditions are favorable for the fungus. Fungicides are used primarily on high-value food crops and in turf and ornamental plant maintenance. They generally kill the fungal spores before they can germinate and infect the plant. Fungicides such as benomyl, metalaxyl, and chlorothalonil are used for a wide variety of crops, turf, and ornamental plants.

Nematicides are targeted at nematodes which infect plant roots and stunt or kill the crop. They are always applied to the soil as that is where the target occurs. Nematicides are generally non-selective, killing most everything they contact in the soil.

Why are pesticides used in agriculture?

Pests have affected crop production since man first started planting seeds. Crop damage from insects, fungi, and weeds can reduce yields and crop quality or even kill the crop in some cases. As a result, farmers have always sought ways to reduce this damage. Pest control using chemicals such as sulfur or plant extracts has been around for thousands of years. The first synthetic pesticides were discovered in the late 1930s and early 1940s and thousands have been developed since.

Pesticide use became widespread in part because the early results were so promising. Pests which farmers had battled for centuries seemed to be eliminated quickly and easily with these sprays. In many cases, less labor was required to produce a crop since hand or mechanical weeding was no longer necessary. As a result, yields increased and more acres could be managed by a farmer.

What are the risks associated with pesticides?

One problem which became evident in the early years of pesticide application was that pests developed resistance to the chemicals; this in turn devastated crops. When large areas are regularly sprayed with a pesticide, a population of pests resistant to the applied chemical can develop. It was learned later that this problem can be reduced by spraying only when necessary and using different pesticides when possible.

Another problem was the effect of pesticides on non-target organisms, which were inadvertently exposed through the food chain. Many of the first pesticides were persistent in the environment and accumulated in animals which consumed contaminated insects or fish. As a result of this problem, most modern pesticides are much less persistent and do not accumulate in the food chain.

There are several potential problems caused by pesticides reaching surface or ground water. The most severe occurrences involve acute toxicity. Acute toxicity occurs when negative effects are seen after exposure to relatively high doses of a pollutant over a short period of time, measured in hours or days. An amount of pesticide reaching a water body and killing fish or other nontarget species would be an example of acute toxicity. Most cases of pesticide acute toxicity are caused by insecticides which drift or wash from fields soon after application. As noted above, insecticides tend to be much more acutely toxic than other pesticides.

The most widespread problem is the occurrence of pesticides in surface and ground water used for drinking water. Because this may result in many people being exposed to the pesticide through their drinking water, there are concerns about chronic toxicity in these groups. Chronic exposure is when the exposure occurs over many years at concentrations which cause no outward effects, but which may increase cancer or other disease risks. Studies have shown that it is highly improbable that the types and concentrations of pesticides found in drinking water pose significant risks. However, most agree that it is prudent to minimize or eliminate pesticide occurrence in drinking water supplies.

The U.S. Geological Survey's (USGS) National Water Quality Assessment Program (NAWQA) has shown widespread herbicide occurrence in agricultural streams and shallow ground water. The presence of insecticides was also frequently detected in streams draining high insecticide use watersheds. The concentrations of these pesticides were measured at levels well below EPA drinking water standards 99% of the time. However, water quality standards are based on exposure to a single chemical or pesticide. In the NAWQA studies, where pesticide contamination of waters was found, there were generally two or more pesticides present (USGS, 1999).

In recent years, research on pesticides in water supplies, including the NAWQA studies, has included the study of pesticide degradation products. Degradation products are the compounds found in the environment as a result of the natural breakdown of the original pesticide or parent compound. They are usually less toxic than the original pesticide. While this document does not directly address pesticide breakdown products or their effects, the issue is an emerging concern and will likely receive more attention in the future.

Pesticide Movement into Surface and Ground Water

Pesticides can reach ground and surface water in a number of ways. Surveys of ground and surface water have found pesticides in many areas of the country. The extent of the contamination is often well defined, but the source or sources of contamination can be quite elusive in some cases. Figures 4b-2 to 4b-4 illustrate the major environmental fates of pesticides and are indicative of how difficult it is to quantitatively assess pesticide fate. However, the sources and problems associated with ground and surface water contamination are described in the following section.

Movement to Surface Water

Importance of pesticide contamination of surface water: About half of the population in the United States gets its water from surface sources. Therefore, pesticide contamination of surface water is of great concern to many. Several studies have shown that water supply reservoirs in the Midwest routinely exceed the health limits for pesticides, although these levels often only occur briefly in late spring after the main application season.

Losses of pesticides to runoff generally range from ≤1 to 5% of applied amounts, depending on various factors. Losses are usually greatest in the 1 to 2 weeks after application, and are highly dependent on storm events. Often, pesticide residues are only detectable in the first storm event after application.

Pesticides can enter surface water from the atmosphere in the form of drift or rainfall. Drift into surface waters can be serious locally if the pesticide is highly toxic to aquatic organisms, as in the case of many insecticides. Rain and fog have been shown to contain pesticide residues, particularly during the spring planting season. However, neither drift nor rain are major contributors to surface water contamination when compared to runoff.

Most pesticide contamination of streams, lakes, and estuaries occurs as a result of runoff from agricultural and urban areas. Runoff carries with it a mix of suspended soil particles and any pesticides which were either attached to the particles or dissolved in surface moisture just before runoff began. The amount of pesticide loss due to runoff is affected by the following factors:

Good soil and water management are also essential for effective pesticide management.

Rain Intensity — Heavy downpours result in minimal infiltration and maximum runoff. If soil is already moist prior to a rainfall event, then runoff will be greater since the soil's capacity to store additional water is reduced.

Surface Conditions — Recently tilled soil and soil with good ground cover have the most resistance to runoff, since water infiltrates relatively easily and the surface is "rough" enough to impede the flow of water. Maximum runoff potential occurs during the month after planting, since the soil is exposed and the crop has not grown large enough to intercept rain and reduce its ability to detach and transport soil particles. Reduced tillage practices that maintain residue on the surface will decrease runoff relative to conventional tillage practices that leave the soil bare and smooth at planting.

Figure 4b-2. Pesticide Fate: Atmosphere

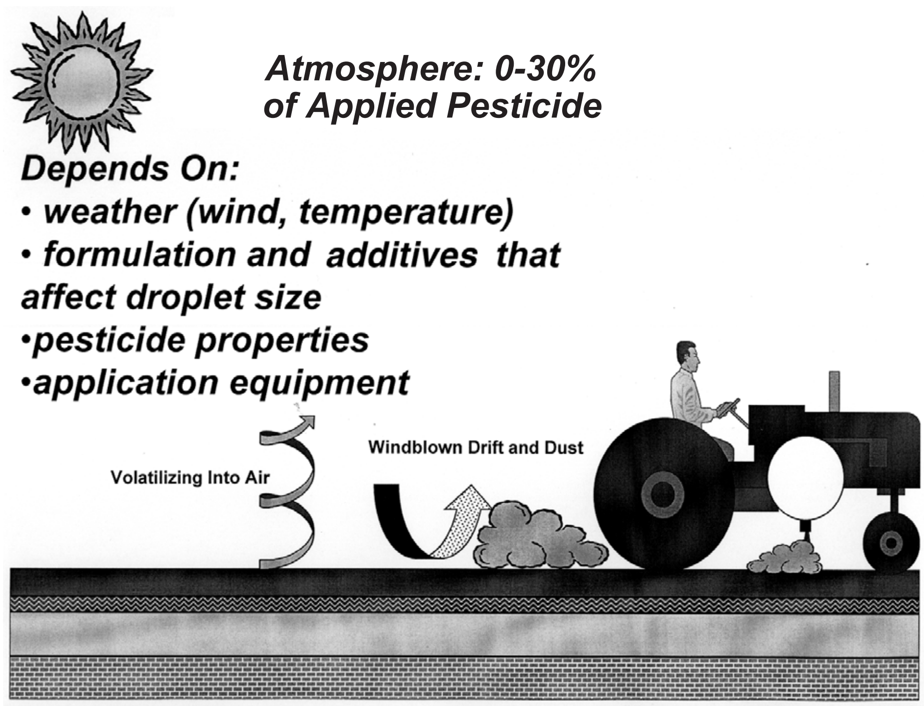


Figure 4b-3. Pesticide Fate: Plant Uptake

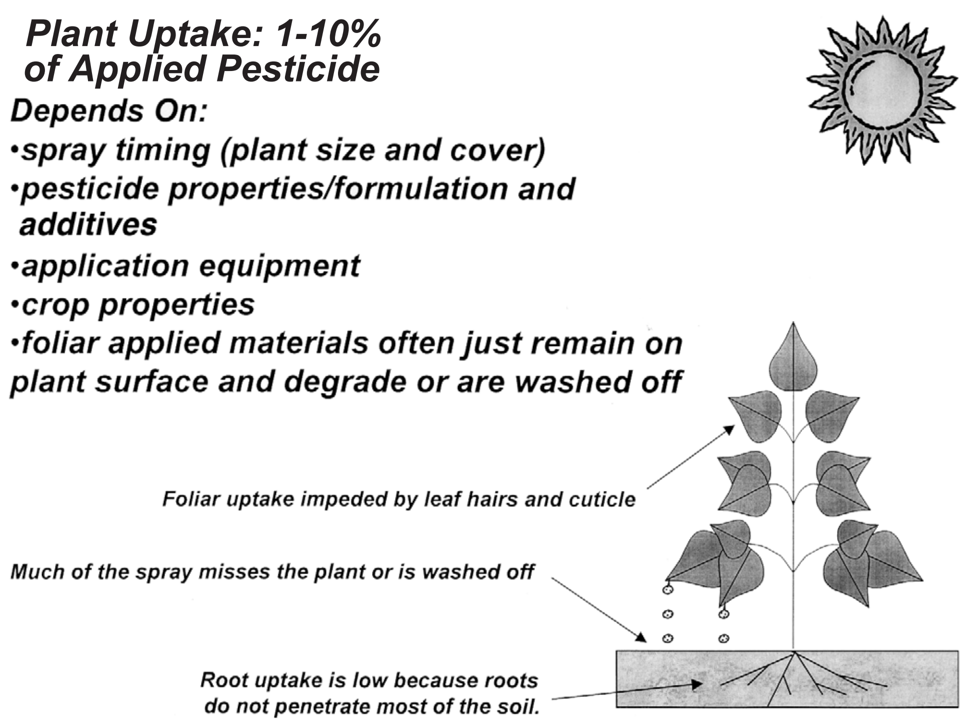
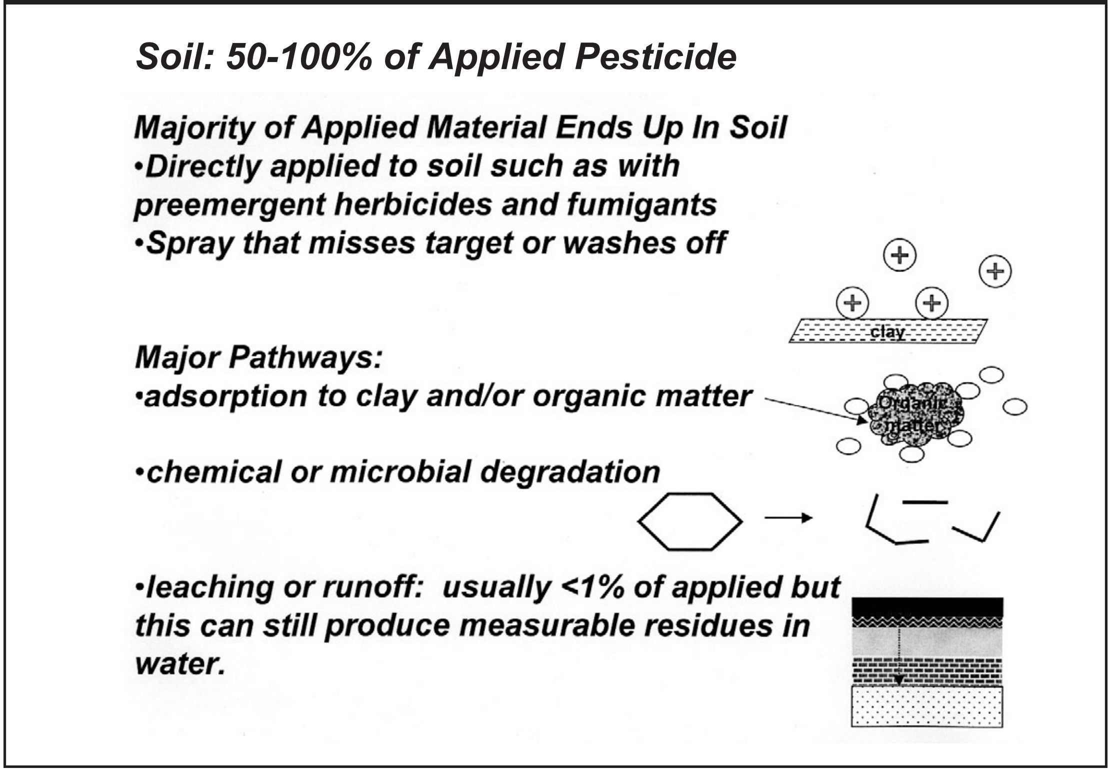


Figure 4b-4. Pesticide Fate: Soil



Length of Slope and Percent Slope — Steeper and longer field slopes increase runoff energy, and the transport of soil and adsorbed pesticides.

Rate and Method of Application — Pesticides tilled or injected into the soil are less likely to be lost in runoff, although the disturbance of the soil by tilling or injection may increase soil (and attached pesticides) losses. Large losses of foliar pesticides in runoff can result if a heavy downpour occurs soon after application. Higher application rates will also generate higher pesticide concentrations in runoff.

Timing — If a runoff event occurs soon after the pesticide is applied, substantial losses can occur.

Vegetated Buffers — The beneficial effects of grassed buffers can be quite substantial, with reductions of pesticide movement into adjoining streams of up to 80 to 90%. The combination of infiltration, reduced overland flow rates, and adsorption in these zones can be quite effective in keeping pollutants in field runoff from being delivered to waterways.

It is important to emphasize that buffers function only under conditions of overland or sheet flow. Pesticides in runoff which moves through a buffer in a ditch or channel have little opportunity to degrade or adsorb before delivery to surface water.

Pesticide Degradation in Surface Waters — Once pesticides enter surface water, their rate of degradation slows considerably compared to degradation rates in soils. A portion of the pesticide may adsorb to the sediment and remain there until a flood event moves the sediment back into the moving water. This cycle of deposition and re-suspension is one of the mechanisms responsible for the presence of low levels of pesticides long after the application season.

Movement to Ground Water

***Importance of pesticides in ground water*:** Approximately half of the U.S. population drinks water from wells; therefore, ground water protection is very important. Once a pesticide reaches ground water, it is very slow to degrade or flush out, so prevention is very important.

Movement of pesticides into ground water can occur through leaching after normal applications or by more direct pathways not related to normal uses (i.e. spills and direct contamination):

- ❐ **Leaching** — Pesticides can be moved downward toward ground water as rain or irrigation water percolates through the soil. Such a leaching process is controlled by the properties of the pesticide, the properties of the soil, the weather, and hydrologic loading.

  Pesticide Properties: There are hundreds of pesticides and each one has a unique set of properties which determine if it is more or less likely to contaminate ground water. The most important are:

  Persistence: measured in amount of time required for 50% to be degraded (half-life). The more persistent a chemical, the more likely it will find its way into ground water.

  Adsorption: measured by how much of the chemical binds to soil, when shaken in water, as opposed to that which dissolves in water. The greater the adsorption ability of a pesticide, the less likely it will leach through the soil.

  Application Rate and Method: measured in amount of active ingredient applied per acre. Pesticides requiring higher application rates may have an increased chance of leaching into ground water. Pesticides applied to growing crops are less likely to have the opportunity to leach than those applied to the soil.

  Soil Properties: Pesticides often are applied to, or wash into, soils, where they may be adsorbed, degraded, or leached into shallow ground water. The properties of the soil that most influence these processes are discussed below. In addition to the soil properties listed here, any management practice (e.g., tillage) that impacts the properties or structure of soil has the potential to affect the movement of pesticides to ground water.

  Organic Matter: measured as a fraction of the soil by weight. Most pesticides bind tightly to organic matter in soil so higher organic matter contents reduce the risk of leaching.

  Clay: measured as a fraction of the soil by weight. Clay can bind many pesticides and it tends to reduce or slow the movement of percolating water. These two effects combined result in lower leaching risk with increasing clay content.

  pH: measured on a scale of 0-14, with most soils falling in the 5-8 range. Generally, lower pH values will reduce leaching of pesticides and increase their rate of degradation.

Depth to Ground Water: not exactly a soil property but often closely related. The farther pesticide residues have to leach to reach ground water, the greater the chance of biological or chemical degradation. Although degradation rates decline rapidly below the root zone, most pesticides will degrade slowly as they move toward the ground water table.

Weather: The degradation and movement of pesticides in soil is highly influenced by the weather. Warmer or cooler temperatures will speed up or slow down degradation, respectively.

Hydrologic Loading: The addition of water to areas of pesticide application is key to the transport of pesticides toward ground water. Precipitation or irrigation in excess of evapotranspiration rates and soil water holding capacity can move pesticides deeper into the soil profile and increase the likelihood of pesticides leaching into ground water aquifers.

- ❒ **Spills** — Although some soils are very good at adsorbing and degrading applied pesticides, high concentrations of pesticides which result from spills overwhelm all these processes. Highly contaminated soils can be a long-term source of contamination because percolating water will continue to carry the pesticide into the ground water. Although the movement of pesticide residues is through leaching, a spill is still considered a point source.

- ❒ **Direct Contamination** — Ground water can be contaminated directly in many ways. Some of the most serious include backsiphoning, surface water movement into wells, or drainage into limestone channels or sink-holes. These contamination problems can almost always be prevented. Once they occur, however, the point of entry becomes a point source for contamination. A plume of contamination moves slowly away from the source and can spread to contaminate many downgradient wells.

  Well contamination is often the result of a lack of proper backflow prevention devices or poor well construction. Problems such as a poor or absent casing, lack of grouting, location in a low spot where water accumulates, or capping below the soil surface are all invitations for contaminated surface water to enter the well. High nitrates and bacterial contamination are often associated with these problems.

Pesticide Management Practices and Their Effectiveness

The practices set forth below have been found by EPA to be representative of the types of practices that can be applied successfully to achieve the management measure described above. Additional information about individual practices, their purpose, and how they work is presented in Appendix A.

1. ***Inventory current and historical pest problems, cropping patterns, and use of pesticides for each field.***

   The purpose of this procedure is to assist the grower in evaluating the potential for water contamination at the site and to determine IPM strategies which may be applied to the operation. Much of this information is important for many aspects of farm operation beyond pollution prevention. This inventory can be accomplished by using a farm and field map, and by compiling the following information for each field:

- ❒ *Crops to be grown and a history of crop production*. Certain IPM strategies, such as crop rotation, require this information.
- ❒ *Information on soil types*. Different soils can have very different susceptibility to either runoff or leaching losses of applied pesticides.
- ❒ *The exact acreage of each field.* This information can be used to check application rates as well as yields.
- ❒ *Records on past pest problems, pesticide use, and other information for each field.* By keeping these records, the grower can evaluate options for pest management such as crop rotations and alternative pesticides.

2. ***Evaluate the soil and physical characteristics of the site including mixing, loading, and storage areas for potential for the leaching and/ or runoff of pesticides.*** The most important types of features for evaluation include:

- ❒ *Sinkholes, drainage wells, abandoned wells, and karst topography which allow direct access to ground water.* These allow surface water carrying sediment, bacteria, and pesticides to quickly enter and contaminate the ground water.
- ❒ *Proximity to surface water.* Pesticides should not be used directly adjacent to surface water because of the high potential for pesticide contamination from runoff and drift. An untreated buffer around the surface water will provide a measure of protection.
- ❒ *Runoff potential.* Steeper slopes, heavier soils, and conventional tillage all increase the runoff potential for a field. Greater amounts of organic matter and clay increase the ability of the soil to bind the pesticide. Conservation tillage tends to increase infiltration and decrease the amount of runoff, further reducing potential pesticide losses.
- ❒ *Aerial drift.* Fields with their longer dimension at 90 degrees to the prevailing wind direction will have lower drift potential than those parallel to the wind.
- ❒ *Soils with a high risk of erosion.* Cropping practices such as no-till can greatly reduce the runoff potential for pesticides on steep slopes with heavy soils.
- ❒ *Soils with poor adsorptive capacity.* Low organic matter (<1%) and clay content reduces the ability of the soil to bind applied pesticides and prevent them from leaching through to ground water.
- ❒ *Highly permeable soils.* Often soils with poor adsorptive capacity also have high sand contents which allow water to percolate rapidly through them. This allows any pesticides present to move quickly downward before they are degraded by the more abundant microbes in the surface horizons.
- ❒ *Shallow aquifers.* A shorter distance between the application zone in the surface soil to the aquifer means less opportunity for binding and degradation of the pesticide.

- ❒ *Wellhead protection areas.* Private wells should have a 100-foot buffer in which no pesticides or fertilizers are applied. Public water supply wells may require a larger buffer. The buffer minimizes the risk of agricultural chemicals leaching into the ground water immediately adjacent.

3. ***Use IPM strategies to minimize the amount of pesticides applied***, including:

- ❒ *Scouting fields for pest problems.* Most universities have scouting guides for farmers which will provide guidance for procedures appropriate to their area. Often county extension staff provide training for scouting, or a farmer may be able to hire a consultant to provide this service. Many agricultural retailers also provide scouting services as a part of their pesticide application contracts. The key is to know how and where to look for pests and their correct identification. For weeds, a farmer may rely on problems from the previous year or he may walk a specified length of row to count weed seedlings. For insects, a sweep net may be brushed through the crop and the insects identified and counted to estimate the potential for crop damage.
- ❒ *Determine the economic threshold for pests.* This is also information that is usually available from local extension offices. The expected value of the crop and the anticipated losses caused by the pest are estimated against the cost of an application before any sprays occur.
- ❒ *Use varieties of crops resistant to pests.* Resistant varieties usually require fewer pesticide applications.
- ❒ *Use crop rotation.* Crop rotations interrupt pest buildup by eliminating the host plants or by allowing the application of pesticides which reduce pest populations. An example is a corn-soybean rotation, in which broadleaf weeds are more easily controlled in the corn crop and grass weeds are more easily controlled in the soybean crop.
- ❒ *Foster biological controls.* Identifying the pest properly and recognizing beneficial insects is key. If a spray is necessary, select a pesticide which is the most specific to the pest and least toxic to non-target species. Natural enemies can be introduced and their habitats preserved. Pheromones can be used to monitor populations, disrupt mating, or attract predators or parasites.
- ❒ *Use of improved tillage practices* such as ridge tillage.
- ❒ *Use of cover crops* in the system to promote water use and reduce deep percolation of water that contributes to leaching of pesticides into ground water.
- ❒ *Destruction of pest breeding, refuge, and overwintering sites* (this may result in loss of crop residue cover and an increased potential for erosion).
- ❒ *Use of mechanical destruction of weed seed through the use of tillage techniques*. Erosion control goals must also be considered when tillage alternatives are being examined.
- ❒ *Diversification of habitat.* The abundance of pests is greatly influenced by the environment created by the farmer. Monocultures

create a simple environment in which pests may have little or no competition or predators. Having a broad array of plant species as crops and in borders diversifies the habitat and dampens pest populations.

- ❒ *Use of trap crops.* A species or variety of plant which is more attracted to pests than the main crop can be planted earlier or in an adjacent area. This will concentrate the pests in a smaller area where they can be controlled with a pesticide, thus avoiding a wider pesticide application.
- ❒ *Use of allelopathic characteristics of crops*. There is evidence that some crops can naturally inhibit the growth of pest populations. For example, a rye cover crop may reduce weed populations in subsequent crops.
- ❒ *Use of timing of field operations* (planting, cultivating, irrigation, and harvesting) to minimize application and/or runoff of pesticides.
- ❒ *Use of efficient application methods, e.g., spot spraying and banding of pesticides.* Often pest problems occur primarily in one portion of the field, allowing for targeted pesticide application. Banding may provide protection of the crop without the entire area being sprayed.

4. ***When pesticide applications are necessary and a choice of material exists, consider the persistence, toxicity, and runoff and leaching potential of products along with other factors, including current label requirements, in making a selection.*** This is a complex area and most pesticide users will not have much of the information necessary to make such judgements. The leaching potential for many pesticides has been estimated in several ways and are in general agreement with each other. One example is the PLP, or Pesticide Leaching Potential, which is an index of persistence and leaching characteristics of each chemical (Table 4b-1).

   Table 4b-1 may be useful as a starting point, but other information may be available from State agencies, NRCS, or universities.

   Users must apply pesticides in accordance with the instructions on the label of each pesticide product and, when required, must be trained and certified in the proper use of the pesticide. Labels include a number of requirements including allowable use rates; classification of pesticides as "restricted use" for application only by certified applicators; safe handling, storage, and disposal requirements; and other requirements. Users should contact their state and/or federal pesticide program with questions concerning specific requirements.

   Grower practices can have significant impact on the movement of pesticides into surface water. Tillage practices, incorporation, and filter strips all provide significant reductions in pesticide movement from fields to surface water in most cases (Tables 4b-2, 4b-3). Generally, practices which slow runoff, increase infiltration, and trap sediment tend to reduce pesticide losses.

5. ***Maintain records of application of restricted use pesticides (product name, amount, approximate date of application, and location of application of each such pesticide used) for a 2-year period after use, pursuant to the requirements in section 1491 of the 1990 Farm Bill.***

Table 4b-1. Typical pesticide leaching potential (PLP) index values calculated using commonly reported pesticide properties, and estimated fraction hitting the soil for six example herbicides (NCCES, 1994).

Common Name	Trade Name	Application Method[a]	PLP Index[b]
Herbicides:			
Acifluoren	Blazer	f	40
Alachlor	Lasso	s	52
Ametryn	Evik	s	50
		f	46
Amitrole	Amitrole-T	f	53
Asulam	Asulox	f	51
Atrazine	AAtrex	f, ph7	56
		s, ph7	60
		s, ph5	52
		s, ph7, noncrop	66
		s, ph5, noncrop	57

[a]s = soil application and f = foliar application of pesticide. pH is given where differences have a known effect and data are available. Noncrop indicates difference in rates, usually higher than crop uses.

[b]PLP values range from 0 (no leaching potential) to 100 (maximum leaching potential).

Source: North Carolina Cooperative Extension Service. 1994. Soil Facts: Protecting Groundwater in North Carolina, a Pesticide and Soil Ranking System. North Carolina State University. AG-439-31.

Table 4b-2. Effect of BMPs on pesticide losses compared to conventional tillage or no filter strips.

Practice	Range of Reductions	Average	Reference
Ridge Till	-33 – 65	30	Baker and Johnson, 1979
No-Till	-98 – 9	51	Baker and Johnson, 1979
	29 – 100	77	Glenn and Angle, 1987
	64 – 100	86	Hall et al., 1991
	85 – 99	92	Hall et al., 1984
	6 – 41	21	Franti et al., 1995
	41	—	Seta et al., 1993
	100	—	Isensee and Sadeghi, 1993
Contour Ridges	53 – 100	79	Ritter et al., 1974
Incorporation	26 – 75	—	Hall et al., 1983
	24 – 36	30	Baker and Laflen, 1979
	7–79	52	Franti et al., 1995
Filter Strips	28 – 31	—	Asmussen et al., 1977
	4 – 14	—	Rhode et al., 1980
	9 – 35	22	Hall et al., 1983
	40 – 72	56	Mickelson and Baker, 1993
	50 – 74	63	Misra et al., 1994
	15 – 72	45	Misra, 1994

Table 4b-3. Summary of buffer studies measuring trapping efficiencies for specific pesticides. K_{oc} values listed for each pesticide are from the NRCS Field Office Technical Guide, Section II Pesticide Property data base (USDA-NRCS, 2000).

Pesticide	K_{oc}	Study reference	Percent pesticide trapped
Highly adsorbed pesticides			
Chlorpyrifos	6,070	Boyd, et al., 1999	57–79
		Cole, et al., 1997	62–99
Diflufenican	1,990	Patty, et al., 1997	97
Lindane	1,100	Patty, et al., 1997	72–100
Trifluralin	8,000	Rhode, et al., 1980	86–96
Moderately adsorbed pesticides			
Acetochlor	150	Boyd, et al., 1999	56–67
Alachlor	170	Lowrance, et al., 1997	91
Atrazine	100	Arora, et al., 1996	11–100
		Boyd, et al., 1999	52–69
		Hall, et al., 1983	91
		Hoffman 1995	30–57
		Lowrance, et al., 1997	97
		Mickelson and Baker 1993	35–60
		Misra, et al., 1996	26–50
		Patty, et al., 1997	44–100
Cyanazine	190	Arora, et al., 1996	80–100
		Misra, et al., 1996	30–47
2,4-D	20	Asmussen, et al., 1977	70
		Cole, et al., 1997	89–98
Dicamba	2	Cole, et al., 1997	90–100
Fluormeturon	100	Rankins, et al., 1998	60
Isoproturon	120	Patty, et al., 1997	99
Mecoprop	20	Cole, et al., 1997	89–95
Metolachlor	200	Arora, et al., 1996	16–100
		Misra, et al., 1996	32–47
		Webster and Shaw 1996	55–74
		Tingle, et al., 1998	67–97
Metribuzin	60	Webster and Shaw 1996	50–76
		Tingle, et al., 1998	73–97
Norflurazon	600	Rankins, et al., 1998	65

Section 1491 requires that such pesticide records shall be made available to any Federal or State agency that deals with pesticide use or any health or environmental issue related to the use of pesticides, on the request of such agency. Section 1491 also provides that Federal or State agencies may conduct surveys and record the data from individual applicators to facilitate statistical analysis for environmental and agronomic purposes; however, in no case may a government agency release data, including the location from which the data was derived, that would directly or indirectly reveal the identity of individual producers. Section 1491 provides that in the case of Federal agencies, access to records maintained under section 1491 shall be through the Secretary of Agriculture or the Secretary's designee. This section also provides that State agency requests for access to records maintained under section 1491 shall be through the lead State agency so designated by the State.

Section 1491 includes special access provisions for health care personnel. Specifically, when a health professional determines that pesticide information maintained under this section is necessary to provide medical treatment or first aid to an individual who may have been exposed to pesticides for which the information is maintained, upon request persons required to maintain records under section 1491 shall promptly provide records and available label information to that health professional. In the case of an emergency, such record information shall be provided immediately.

Operators should consider maintaining records beyond those required by section 1491 of the 1990 Farm Bill. For example, operators may want to maintain records of all pesticides used for each field, i.e., not just restricted use pesticides. These records will be useful in setting up IPM programs and in crop rotation and management decisions. In addition, operators may want to maintain records of other pesticide management activities such as scouting records or other IPM techniques used and procedures used for disposal of remaining pesticides after application. Operators should also check with state and local agencies regarding record keeping requirements.

6. ***Use only the recommended amount of pesticide for the problem you or a professional have identified and determined to merit pesticide application.***

7. ***Recalibrate and repair application equipment, including chemigation equipment, at least each spray season. Use anti-backflow devices on hoses used for filling tank mixtures and on chemigation systems.*** Calibration of pesticide spray equipment at least once each spray season is critical to ensuring that proper application rates are maintained.

   As replacement equipment is needed, purchase new, more precise application equipment and other related farm equipment (including improved nozzles, computer sensing to control flow rates, radar speed determination, electrostatic applicators, and precision equipment for banding and cultivating).

8. ***Solid pad for mixing and loading pesticides.***

EPA's Office of Pesticide Programs Promotes Registration of Lower Risk Pesticides

Reduced risk conventional pesticides

Since 1993 EPA's Office of Pesticide Programs has encouraged pesticide companies to register lower risk pesticides. The Agency expanded this program in 1998 to further encourage replacements for organophosphate (OP) pesticides, a class of neurotoxins. EPA's Reduced-risk Initiative expedites the registration of *conventional* pesticides that the Agency believes pose less risk to human health and the environment than existing alternatives. The goal of the program is to quickly register commercially-viable alternatives to riskier pesticides such as neurotoxins, carcinogens, reproductive and developmental toxicants, and ground and surface water contaminants. Reduced risk pesticides generally have low human toxicity; low risk to non-target terrestrial and aquatic plants and animals; reduced application rates; rapid field degradation; low potential to contaminate ground or surface water; and work well with integrated pest management programs. *Biological* pesticides which also have many of these desirable characteristics are described below.

The major incentive for pesticide companies to register reduced risk conventional pesticides is a one to two year reduction in the time to get their product on the market. This allows the chemical to be introduced into the market at the earliest possible time and displace riskier alternatives as soon as possible. It also allows the registrant to recoup their investment costs sooner and gain several additional growing seasons under patent. In addition, although companies are not allowed to put a reduced-risk claim on their labels, EPA believes that companies use the reduced-risk status to marketing advantage. Some reduced risk pesticides have already gained large market shares (up to 70%) over riskier compounds.

Biological Pesticides

Office of Pesticide Programs also encourages the registration of biological pesticides. Biological pesticides are expedited in a fast-track registration process by their own working group, the Biopesticides and Pollution Prevention Division. Examples include microbial pesticides (bacteria, viruses or other microorganisms used to control pests), and biochemical pesticides, such as pheromones (insect mating attractants), insect and plant growth regulators, and hormones used as pesticides. Most biological pesticides are applied at very low rates, are highly volatile, or are applied in bait, trap, or "encapsulated" formulations and thus result in less exposure (and less likelihood of adverse effects to humans and the environment than from the use of most conventional pesticides). Among these new pesticides approved are the first plant pesticide products, which are agricultural plants that are altered to produce proteins toxic to insects that destroy crops. As with reduced risk conventional pesticides, a major incentive to pesticide companies to register biological pesticides is a reduction in the time to get their product on the market and the benefits that accrue from an earlier release date.

For more information on reduced risk pesticides, contact the EPA Reduced Risk Pesticide Coordinator, in the Registration Support Branch, Registration Division, Office of Pesticide Programs.

Factors in the Selection of Management Practices

The best way to control pests in crops is to know the crop and pest well enough to determine a control plan which maximizes crop production while minimizing environmental impacts. This is often a combination of cultural, biological, and chemical practices. Cultural controls include tillage, crop rotations, resistant varieties, and varying planting or harvest dates. Biological controls involve encouraging or introducing natural enemies of the pest and managing the crop environment to the disadvantage of the pest. Chemical controls should involve a selection process which selects a pesticide which results in the greatest economic benefit for the least environmental cost. Such a determination requires knowledge and information which are beyond the average grower. However, many states have guides to assist in pesticide selection.

Relationship of Pesticide Management Measures to Other Programs

Under the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA), EPA registers pesticides on the basis of evaluation of test data showing whether a pesticide has the potential to cause unreasonable adverse effects on humans, animals, or the environment. Data requirements include environmental fate data showing how the pesticide behaves in the environment, which are used to determine whether the pesticide poses a threat to ground water or surface water. If the pesticide is registered, EPA imposes enforceable label requirements, which can include, among other things, maximum rates of application, classification of the pesticide as a "restricted use" pesticide (which indicates that a pesticide may have adverse effects on the environment and/or the applicator and restricts use to certified applicators trained to handle such pesticides), or restrictions on use practices. FIFRA allows States to develop more stringent pesticide requirements than those required under FIFRA, and some States have chosen to do this. The EPA and the U.S. Department of Agriculture Cooperative Extension Service provide assistance for pesticide applicator and certification training in each State.

Cost and Savings of Practices

Costs

In general, most of the costs of implementing the pesticide management measure are program costs associated with providing additional educational programs and technical assistance to producers to evaluate pest management needs and for field scouting during the growing season.

One of the most important IPM practices is scouting, which carries with it a cost to the producer. High and low scouting costs are given for major crops in each of the coastal regions (Table 4b-4). These costs reflect variations in the level of service provided by various crop consultants. For example, in the Great Lakes region, the relatively low cost of $4.95 per acre is based on five visits per season at the request of the producer. Higher cost services include scouting and weekly written reports during the growing seasons. Cost differences may also reflect differences in the size of farms (i.e., number of acres) and distance between farms.

The variations in scouting costs between regions and within regions also occur because of differences in the provider of the service. For example, in some states the Cooperative Extension Service provides scouting services and training at no cost or for a nominal fee. In other areas, farmer cooperatives have formed crop management associations to provide scouting and crop fertility/pest management recommendations. There are also consulting firms and agricultural retailers with scouting expertise.

Scouting costs also vary by crop type. Scouting services for high-value cash crops, such as fruits and vegetables, must be very intensive given that pest damage is permanent and may make the crop unmarketable.

Another issue regarding the cost of pesticide management practices is selection of the tillage system and direct and indirect costs associated with that system. Conservation tillage or no-till practices often rely on the use of herbicides to control weeds rather than multiple passes with a cultivator employed in conventional tillage, which mechanically destroy the weeds. When deciding between conservation versus conventional tillage, the direct costs of buying more pesticides (and specific pesticides) for no-till must be weighed against the cost of running more equipment in the field for conventional tillage. Corn production under conventional tillage requires an average of more than three passes through the field to cultivate, while no-till may only require one pass to plant and spray herbicides. Since each cultivation pass costs nearly seven dollars per acre, production costs may increase by more than $14/acre for conventional tillage compared to no-till, minus any additional costs of herbicides.

Savings

Most of the savings of implementing the pesticide management measure are associated with a reduction in the amount of pesticides used. IPM usually requires less pesticide use, thereby reducing the cost of production and increasing the profitability of the crop. In a review of 61 studies of IPM impacts on crop yield, pesticide use, and economics, pesticide use declined in seven of the eight commodities evaluated (Norton and Mullen, 1994; Table 4b-5). Some studies found increased use of pesticides with IPM due to increased awareness of pest problems, but the majority found reductions.

An additional benefit is associated with the use of no-till practices. Soil losses are reduced by up to 90% in no-till compared to conventional tillage, reducing both the indirect costs of erosion and consequent crop yield losses and also adverse environmental impacts of sedimentation of surface water bodies. Yields with conservation tillage are often reduced when a farmer first experiments with it, as it is a new practice which requires new skills and equipment. However, this situation usually changes with time. An added benefit of no-till is that considerable time is saved by only needing to work the field once instead of three or more times.

Table 4b-4. Estimated scouting costs (dollars/acre) by coastal region and crop in the coastal zone in 1992 (EPA, 1992a).

COASTAL REGION	Corn	Soybean	Wheat	Rice	Cotton	Fresh Market Vegetables[a]	Hay[b]
Northeast							
Low	5.50	NA	3.75	—	—	25.00	2.50
High	6.25	NA	4.50	—	—	28.00	2.75
Southeast							
Low	5.00	3.25	3.00	8.00	6.00	30.00	2.00
High	6.00	4.00	3.50	12.00	8.00	35.00	3.00
Gulf Coast							
Low	6.00	4.50	—	5.00	6.00	35.00	—
High	8.00	6.50	—	9.00	9.00	40.00	—
Great Lakes							
Low	4.95	4.25	3.75	—	—	—	4.75
High	5.50	5.00	4.00	—	—	—	5.25
West Coast							
Low	NA	NA	3.50	NA	6.75	32.00	NA
High	NA	NA	5.50	NA	9.30	38.00	NA

NA = not available
— = not applicable
[a] Most fresh market vegetables are produced under a regular spraying schedule.
[b] Scouting costs for hay are based on alfalfa insect inspection. The higher cost in the Great Lakes region includes pesticide and soil sampling.

Table 4b-5. Summary of results of farm-level economic evaluations of IPM programs.

Average	Percent		Percent				
Commodity	States	Number of Studies	Percent Change in Pesticide Use[a]	Change in Production Cost with IPM[a]	Percent Yield Change with IPM[a]	Change in Net Returns Per Acre[a]	Level of Risk with IPM
Cotton	TX, GA, MS, NC, SC, LA, MO, TN, AZ, NM, CA, AR	18	-15	-7	+29	+79	decreased
Soybeans	NC, VA, MD GA, IN	7	-35	-5	+6	+45	decreased
Corn	IN, IL, and 10 other states	3	+20	+3	+7	+54	—
Vegetables and Flowers	CT, CA, MA, TX, FL, OH, NY, HI	15	-43	Quality increased in 4 studies and remained the same in others			
Fruits	NY, MA, WA, NJ, CA, CT	8	-20	0	+12	+19	—
Peanuts	GA, TX, OK, NC	5	-5	-5	+13	+100	—
Tobacco	NC	2	-19	—	0	+1	—
Alfalfa	OK, WI, Northwest	3	-2	—	+13	+37	decreased
Unweighted Average[b]			-14.9	-2.8	+11.4	+47.8	decreased

[a] For those producers that adopted the specified IPM practices compared to those that did not.
[b] Weighting is not possible without an accurate accounting of the acreage affected for each commodity in each state.
Source: Norton, G.W. and J. Mullen. 1994. *Economic evaluation of integrated pest management programs: a literature review.* Va. Coop. Ext. Pub. 448-120, Virginia Tech, Blacksburg, VA 24061.