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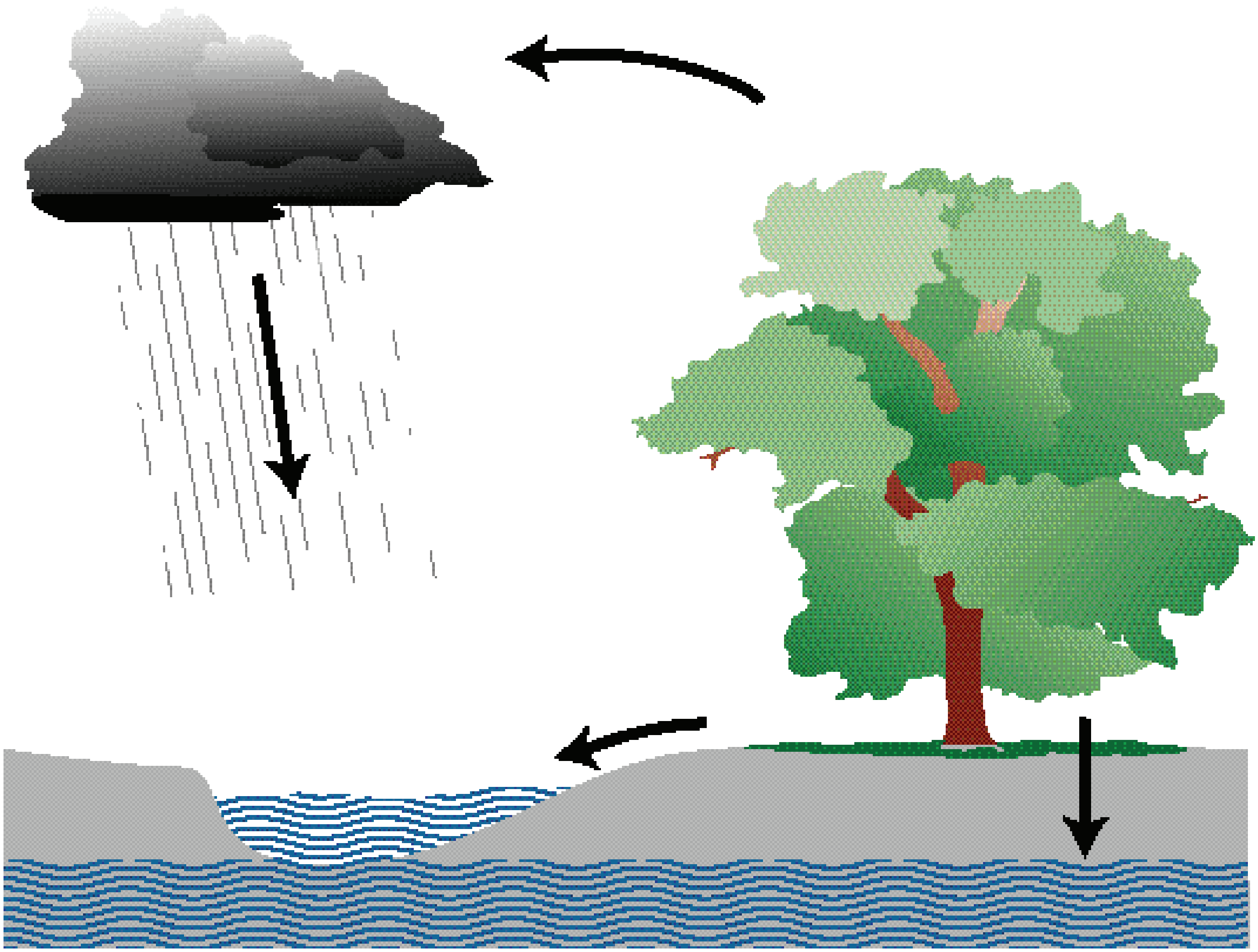
Pesticide Properties That Affect Water Quality



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Three factors are necessary to all life on earth. These are an oxidizing agent (usually oxygen), nutrients and water. Water may be the universal chemical compound required by all living organisms. The chemical content of the water in a specific ecosystem determines what life forms can exist. Humans require water with low levels of minerals and organic material. We also require water with low concentrations of chemical toxins. We consider water with these properties to be high quality water.

Most people in the United States expect high quality water as one of the privileges of modern society. Technology makes it possible to turn on the faucet and have clean, clear water readily available. However, the technology that makes this possible also creates pressure on the very water resources that are now taken for granted.

Why is Water Quality Important?

Water is a part of everyday life, yet it is not an unlimited resource. Fresh water accounts for less than 2.5 percent of all the earth's water. Of all the fresh water on earth, nearly 80 percent is ice in the polar ice caps and glaciers of the world. This leaves only about 0.2 percent of earth's fresh water available for our use (Environmental Protection Agency, 1990).

Since water is the currency of life, we can look at it in terms of money. If $1,000 represented all the water on earth, only about $2 would be available as fresh water. Most of this would be locked up in ice and other unavailable sources. Only a few pennies would be available to spend. So, we can't afford to lose it or waste it.

We depend on water to sustain us, our domestic and wild animals, and the growing plants in forests, fields, yards and gardens. If water becomes contaminated by toxins, it can harm all life forms. Pollution affects all of us—office workers and housewives, the farmer and the field mouse.

Most of the available fresh water is ground water. A much smaller percentage is in rivers, lakes, soil moisture, and the atmosphere. This might appear inadequate. However, if it is of high quality, the amount we have is enough. At present, only about2 percent of ground water in the United States shows pollution. However, an increasing amount of surface water is becoming at least somewhat contaminated (Environmental Protection Agency, 1990).

More than 600 million pounds of pesticides enter the environment each year in the United States. Pesticides control thousands of different weeds, insects and other pests; they protect crops, human health, property and domestic animals almost everywhere; and, they even protect our drinking water from contamination by algae and other dangerous organisms. However, information about the health and environmental effects of pesticides has increased public concerns and led to more regulation of these chemicals.

We must understand how pesticides can pollute water throughout the hydrologic system (Fig. 1).

The contamination of water is directly related to the degree of pollution of our environment. Rainwater flushes airborne pollution from the skies. It then washes over the land before running into rivers, aquifers and lakes. It also seeps into underground aquifers. Irrigation and drinking water come from both surface and ground water. Eventually, all of the chemicals we use can pollute our water supplies (see Fig. 2).

There are many materials that endanger our water quality. Most come from urban and industrial activity. Some, however, come from agriculture. Whether in agricultural operations or in urban environments, the improper application, handling or disposal of pesticides can lead to water pollution. There is reason for optimism, however. Without being oppressive, the regulation of pesticides is reducing pesticide pollution of surface and ground water.

Understanding Pesticides

Pesticides are poisons designed to destroy unwanted life forms. Used properly, modern pesticides can perform their functions without causing significant hazards to humans or the environment. Federal and state laws require the registration of any chemical that claims to control pests, and these laws specify how and where such pesticides can be used.

Pesticides have many uses in homes, gardens, farms, forests and public health. It is difficult to imagine what life would be like without modern pesticides. Yet, it has been less than half a century since they became widely used. Before modern pesticides, humanity was at nature's mercy.

The U.S. farmer, through use of the latest management technol-

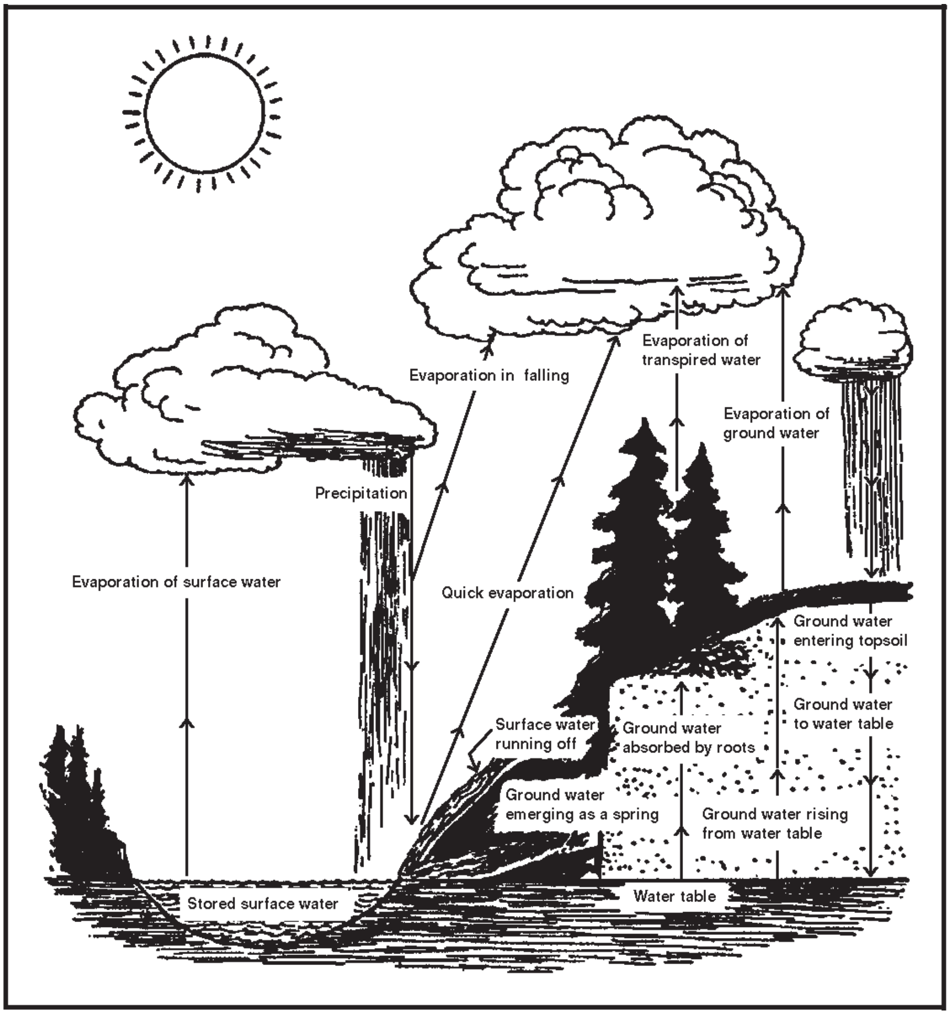

Figure 1. The hydrologic cycle. Water also will flow to the lowest point allowed by the geologic and soil structures present in the environment. (Moon *et al.* 1957.)

ogy, equipment, chemicals and improved hybrid varieties, produces food for this country and the world. In 1994, the average American farmer fed his family and 129 other people, including 97 people in the United States and 32 in other countries. Because most of us don't know much about how our food is produced on farms and ranches, pesticides often are a source of public fear and misunderstanding. Explaining what these chemicals are and what they do is not easy, because most consumers aren't interested in the details. However, it is important to understand both their benefits and hazards.

Classes of Pesticides

Pesticides have several classifications. First, they fall into neat groups on the basis of their target pests—herbicides, insecticides, fungicides and several others. The three most widely used groups of pesticides are the herbicides, insecticides and fungicides. Herbicides eliminate unwanted and dangerous vegetation. Insecticides prevent injury and damage from harmful insects, mites and ticks. Fungicides protect our food supply from dangerous disease organisms.

The Environmental Protection Agency (EPA) classifies pesticides into two types. These are general-use and restricted-use pesticides. If the EPA believes a pesticide is hazardous to humans or the environment, it is placed in the restricted-use category. To use these chemicals, applicators must have training and acquire a special license. These regulations help prevent pollution.

Before a pesticide is registered for use, the EPA estimates its potential to pollute water. Pesticide manufacturers and the EPA use this information to develop specific precautions to prevent pesticides from entering water. These precautions are printed on the product's label. The EPA frequently cancels or restricts pesticides that have a record of contaminating water even when used according to the label.

Modern pesticides ordinarily do not get into water when used according to label directions. However, there is always a potential for water pollution if pesticide applicators do not follow label precautions. Table 1 shows a few common pesticides and their potential as water pollutants. The EPA develops this type of information for all pesticides that it registers.

It is not always possible to use pesticides that pose a low potential risk to water. There are few chemicals to choose from for controlling some pests. When you have to use a chemical that can easily contaminate water, always follow label precautions. Pay special attention to information about the water pollution potential of the chemical you are using. You can then plan your application to reduce the pollution risks. Follow label directions and guidelines at the end of this manual to avoid problems with pollution.

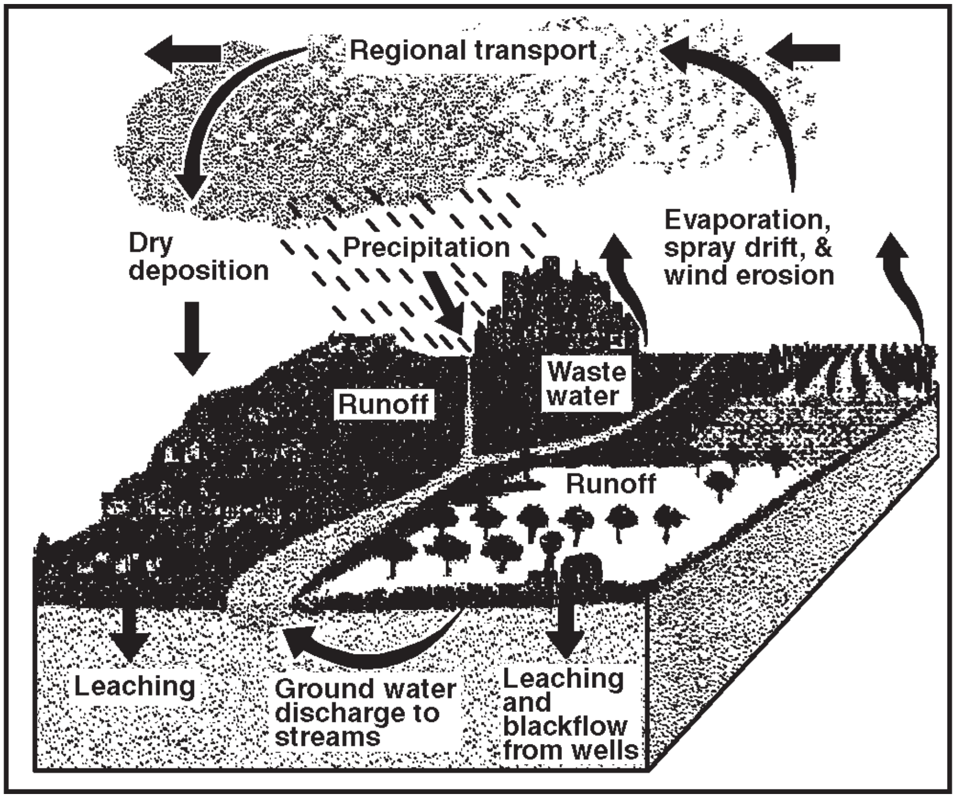

Figure 2. Pathways of pesticide movement in the hydrologic cycle. (After USGS, 1996)

Table 1. Properties of some of the most commonly used pesticides in Texas.

Chemical	Water Solubility	Half-life (days)
Methyl Parathion insecticide	low	5
Carbaryl insecticide	low	10
PCNB fungicide	very low	21
Disulfoton insecticide	low	30
Malathion insecticide	low	1
Chlorthalonil fungicide	very low	30
Phorate insecticide	low	60
Diazinon insecticide	low	40
Methamidophos insecticide	high	6

Ways Agricultural Pesticides Can Contaminate Water

The over-application or misuse of pesticides and other agricultural chemicals (such as fertilizers) can allow these chemicals to enter surface and ground water. Drift, evaporation and wind erosion can carry pesticide residues into the atmosphere. From there they can fall in rain or snow to contaminate lakes and streams. Using excessive amounts of chemicals on open or porous soils where there are shallow water tables can allow pesticides to leach or percolate into the ground water.

Improperly cleaning or disposing of containers, as well as mixing and loading pesticides in areas where residues or run-off are likely to threaten surface or ground water, are other potential sources of contamination. Some pesticide labels and some state statutes specify safe distances from well heads for pesticide mixing and loading.

Agricultural chemicals also can pollute surface water through irrigation return flow and rainfall runoff. Carefully following label directions about proper dosage and application methods can greatly reduce the possibility of water contamination.

Pesticide Properties

Properties that affect a pesticide's potential to pollute water include formulation, toxicity, persistence, volatility, solubility in water, and soil adsorption. Of course, pollution risk also is affected by soil characteristics, application methods, weather and other factors.

Formulation

Pesticides come in several physical forms or formulations that make them easy to store, transport and apply, and that help in controlling target pests. Common formulations include water dispersable granules, wettable powders, dusts, aerosols, solid or liquid baits, granules, emulsifiable and flowable concentrates and solutions. There are other less common formulations designed to give special properties to the pesticide mixture or to take advantage of properties of active ingredients or protect the environment. These include microcapsules, plastic beads, plastic membranes, plastic ropes, controlled release dispensers and others.

While most environmental hazards come from the active ingredient in a pesticide, the way its formulation interacts with the environment determines the overall hazard of a pesticide. Spray formulations can drift with the wind or vaporize into the air. Other formulations can leach into ground water or be carried into surface water by rainfall or irrigation runoff. Even pesticides in formulations that bind them to soil particles can find their way into surface waters if soil is eroded by wind or water.

Toxicity

The active ingredient is the chemical compound in a pesticide that kills or otherwise affects the target pest. Other substances in a pesticide formulation are inert ingredients that act as carriers and preservatives for active ingredients, and also make mixing and application easier.

When determining whether and how to register a pesticide, the EPA considers the toxicity of the active ingredient. Toxicity is determined by the amount required to produce biological effects.

Dose and Effective Dose

A *dose* is the amount of a substance used at one time. Most substances are toxic at large enough doses, but harmless or even beneficial at lower doses. Drinking water is an example. People need to drink some water every day. However, drinking the equivalent of 15 percent of one's body weight can be fatal. Similarly, table salt is absolutely necessary for proper health, but as little as 1 ounce (2 Tablespoons) of table salt would deliver a lethal dose to a 1-year-old child. There is a lethal dose of caffeine in 100 cups of coffee. There is a lethal dose of alcohol in a quart of whiskey. There is a lethal dose of oxalic acid in 20 pounds of spinach. There is a lethal dose of aspirin in 100 tablets. We can compare aspirin with two chemical pesticides. Malathion is about half as toxic as aspirin. Parathion is 70 times more toxic than aspirin. The hazards of pesticide residues are negligible compared to the dangers from common household chemicals and medicines. Table 2 compares toxicities of common products with pesticides.

The effective dose is the amount of a substance needed to kill or otherwise affect a target pest. Amounts less than the effective dose will likely not kill the target pest. Amounts greater than the effective dose will not necessarily be more effective in killing the target pest. Instead, this larger dose may kill more non-target organisms, cost more, and pollute the environment.

Common measures of a chemical's toxicity are the LD_{50} and LC_{50}. These measures refer to doses that kill 50 percent of the animals in a test group. These toxicity terms can apply to target pests or non-target organisms, including humans. The toxicity of a substance determines its proper dosage.

The LD_{50} is the dose of a particular material, taken through the mouth, skin, or inhaled, that is lethal to 50 percent of a group of test animals. The higher an LD_{50} is,

Table 2. Comparative toxicity of pesticides and natural products (1995 Farm Chemicals Handbook; Gosselin *et al.* 1984; SIPRI 1973).

Pesticide	LD_{50} (Rat) in mg/kg	Other product with about equal toxicity
TCDD (Dioxin®)	0.0002	Ricin (castor bean extract)
Saran (GB nerve gas)	0.2	Black widow spider venom
Flocoumafen (rodenticide)	0.25	Strychnine
Aldicarb (insecticide)	0.9	Nicotine alkaloid (free base)
Phorate (insecticide)	1.0	Heroin
Parathion (insecticide)	2.0	Morphine
Carbofuran (insecticide)	8	Codeine
Nicotine sulfate (insecticide)	50	Caffeine
Paraquat (herbicide)	150	Benadryl (antihistamine)
Carbaryl (insecticide)	250	Vitamin A
Acephate (insecticide)	833	Salt substitute (KCl)
Allethrin (insecticide)	1,160	Gasoline
Diazinon (insecticide)	1,250	Tobacco
Malathion (insecticide)	5,500	Castor oil
Ferbam (fungicide)	16,900	Mineral oil
Methoprene (hormone)	34,600	Sugar

the lower the toxicity of the substance. Items with low LD_{50}s are extremely toxic. Basic measuring units used are milligrams of toxin per kilograms of body weight, or "mg/kg." Table 2 shows the LD_{50} values in rats for various pesticides and other familiar chemicals. Aspirin, table salt and other common natural products provide comparisons.

EPA uses LD_{50}s to determine the safe level of pesticide residues in water. The rat is a common test animal for LD_{50}s, but certain environmental studies require LD_{50}s for animals such as rabbits and mice, birds such as bobwhite quail and mallard ducks, fish such as trout and bluegill, and arthropods such as houseflies, honeybees and daphnia (a small fresh-water crustacean).

LC_{50} is another measure of toxicity. LC_{50} stands for the concentration of a material in air or water that will kill 50 percent of the animals tested.

The toxicity of a pesticide is different from the hazard it represents. Hazard refers to the likelihood that a substance will cause harm under certain conditions. For example, the pesticide paraquat is highly toxic. Just a few drops can kill an adult human. There is no antidote for paraquat poisoning. Used properly and stored in a tight container, paraquat has high toxicity and a low hazard. If the contents of the container spill, however, the toxicity remains the same but the hazard increases enormously.

Regulating Toxins in Water

The EPA uses the properties of chemicals to establish standards for toxins in water. The standard for water is the *MCL* or Maximum Contaminant Level. When drinking water exceeds the MCL set for a specific chemical, EPA must take action to increase regulation of the offending product.

EPA sets MCLs at a very low, very safe level. They are less than 1/1,000th of the dose required to have a measurable effect.

Scientists measure pesticide residues in water in parts per million (ppm), parts per billion (ppb), parts per trillion (ppt) and parts per quadrillion (ppq). One part per million is equivalent to one drop of pesticide in 21.7 gallons of water. This is enough to fill a small garbage can. One part per billion is equal to one drop in a 21,700-gallon swimming pool. One part per trillion is one drop in 1,000 swimming pools. One part per quadrillion (ppq) is equal to one drop in a million swimming pools. This is enough water to fill a volume 1 mile long, 1 mile wide and 1 mile deep.

Table 3 shows MCLs for several pesticides found in water. Water containing these amounts of the various pesticides shown is completely safe to drink. Furthermore, a 150-pound man would have to drink at least 75 gallons of water daily to consume even these amounts of pesticides.

Persistence

Persistence describes how long a pesticide remains active. Half-life is one measure of persistence. The half-life of a substance is the time required for that substance to degrade to one-half its original concentration. In other words, if a pesticide has a half-life of 10 days, half of the pesticide normally breaks down by 10 days after application. After this time, the pesticide continues to break down at the same rate. The half-life of a pesticide is not an absolute factor. Soil moisture, temperature, organic matter, available oxygen, microbial activity, soil pH, photodegradation and other factors may cause the half-life of a substance to vary. In general, the longer a pesticide persists in the environment, the more likely it is to move from one place to another and be a potential source of pollution.

Table 3. MCLs for pesticides found in drinking water.

Contaminant	Product type	MCL (ppm)
1,2 Dichloropropane	Fumigant	0.005
2,4-D	Herbicide	0.07
Alachlor	Herbicide	0.002
Aldicarb	Insecticide	0.003
Atrazine	Herbicide	0.003
Dibromochloropropane (DBCP)	Fumigant	0.0002
Ethylene dibromide (EDB)	Fumigant	0.00005
Glyphosate	Herbicide	0.7
Oxamyl	Insecticide	0.2
Picloram	Herbicide	0.5

Volatility

Many pesticides, including several types of herbicides and soil fumigants can escape from soils as gases (see Fig. 2). Some can distil from soils and enter the atmosphere with evaporating water. Pesticide particles in the atmosphere can come back to earth in rain or snow, and then either leach into ground water or be carried by runoff into surface waters.

Water Solubility

The water solubility of a pesticide determines how easily it goes into solution with water. When these compounds go into solution with water they can travel with it as it runs off the land or leaches through the soil. The solubilities of materials such as pesticides are usually given in parts per million (ppm), or in some cases as milligrams per liter (mg/l). The solubility of a substance is the maximum number of milligrams that will dissolve in 1 liter of water.

Simply being water soluble does not mean that a pesticide will leach into ground water or run off into surface water. However, solubility does mean that if a soluble pesticide somehow gets into water, it will probably stay there and go where the water goes. Some pesticides must be somewhat soluble in water to work properly. Others cannot be water soluble to work properly. Manufacturers and the EPA consider solubility carefully when registering a pesticide product. It is important not only to apply pesticides correctly, but also to mix, load, handle and dispose of pesticides and their containers according to label directions. Care with clean-up and disposal is critical when handling pesticides that are soluble in water.

Soil Adsorption

Soil adsorption is the tendency of materials to attach to the surfaces of soil particles. If a substance is adsorbed by the soil, it stays on or in the soil and is less likely to move into the water system unless soil erosion occurs. A soil's texture, structure and organic matter content affect its ability to adsorb chemicals. If you don't know what type of soil you have, send a sample to a laboratory for analysis. Once you know your soil type you can find out its potential risk for pollution by referring to a U.S.D.A. publication called "Soil Ratings for Determining Water Pollution Risks for Pesticides."

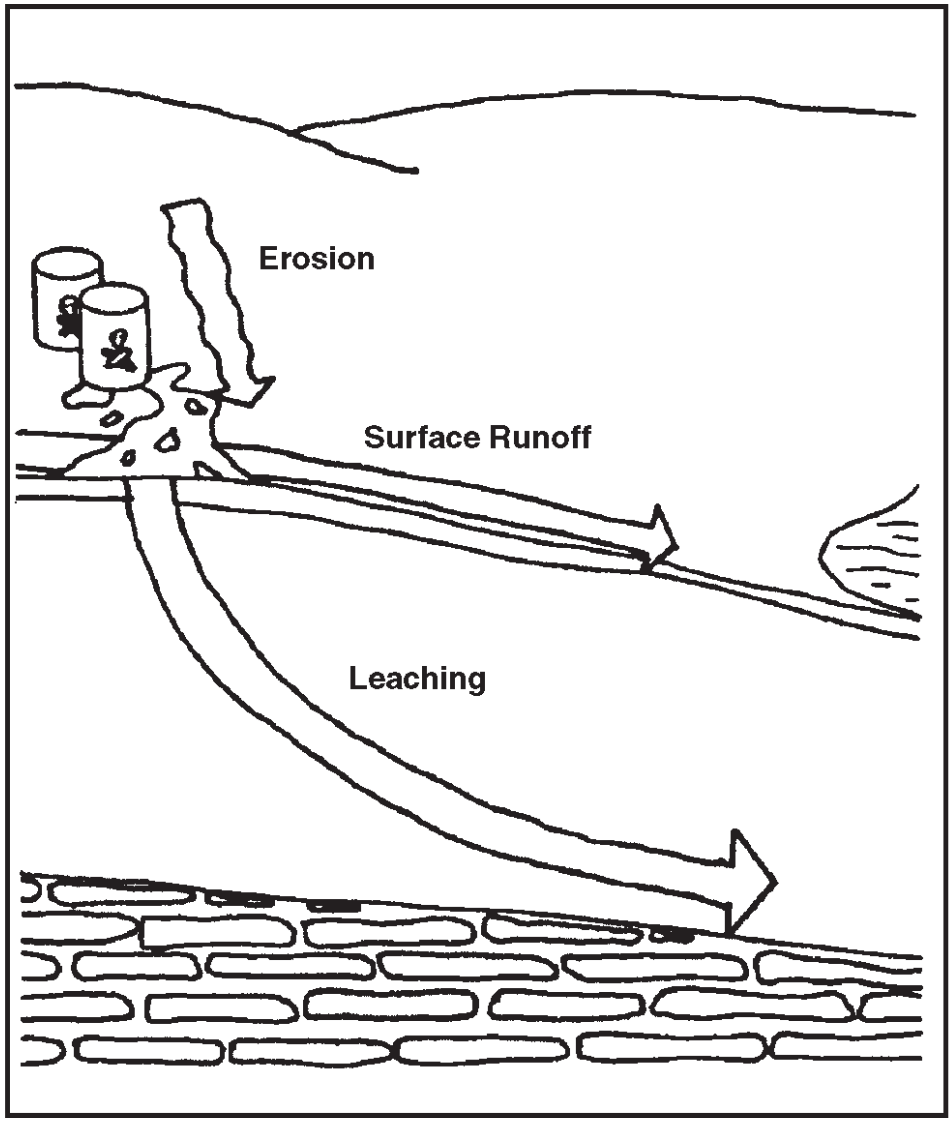

Figure 3. Pesticides can pollute water through either surface runoff or leaching.

How Pesticides Enter Surface and Ground Water

Pesticides can enter water through surface runoff, leaching or erosion. Water that flows across the surface of the land, whether from rainfall, irrigation, snow melt or other sources, always flows downhill until it meets a barrier, joins a body of water, or begins to percolate into the soil. Some pesticides and fertilizers can be carried along with runoff.

Wind and water can erode soil that contains pesticide residues and carry them into nearby bodies of water. Even comparatively insoluble pesticides and pesticides with high soil adsorption properties can move with eroding soil.

With increasing frequency, soil-applied pesticides also are being found in ground water across the U.S., and regulating agencies are taking action to prevent this from occurring. Pesticides have to have several characteristics before they pose a risk to ground water. They have to be water soluble enough to move in the soil. They have to persist long enough to be carried beyond the region of bacterial activity in the soil. They have to be applied at rates high enough to allow them to persist. They have to be applied to soils that will not bind them tightly or deactivate them. They must be applied in regions where climatic factors, including precipitation, will allow them to move through the soil. And, they have to be applied in regions where ground water exists and where it is shallow enough for substances leaching from the surface to reach it.

Pesticides that enter water supplies can come either from point sources or from non-point sources (Fig. 4). Point sources are small, easily identified objects or areas of high pesticide concentration such as tanks, containers or spills. Non-point sources are broad, undefined areas in which pesticide residues are present.

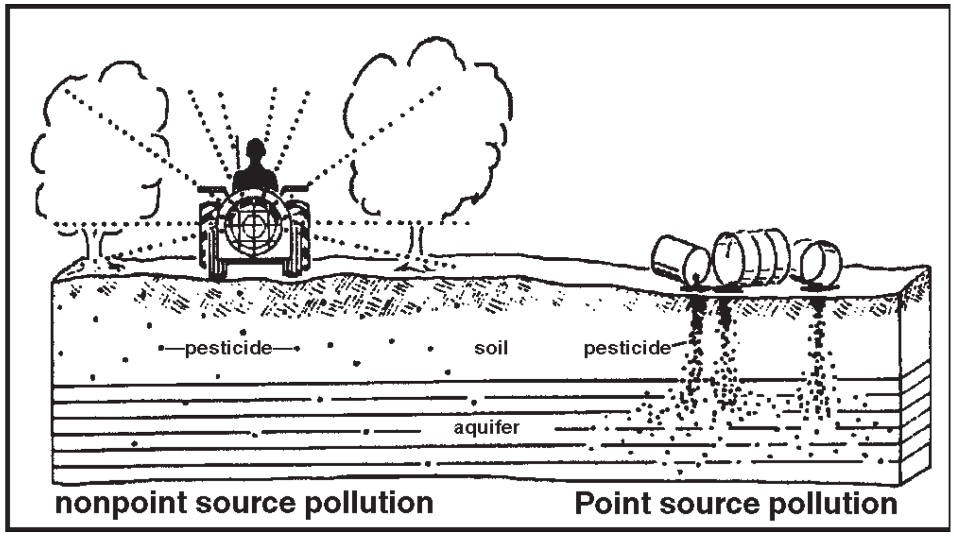

Figure 4. Point and non-point source pollution.

Insecticides

By far, insecticides are the largest group of pesticides. Insecticides are chemicals used to kill, repel, alter the growth patterns, or manipu-

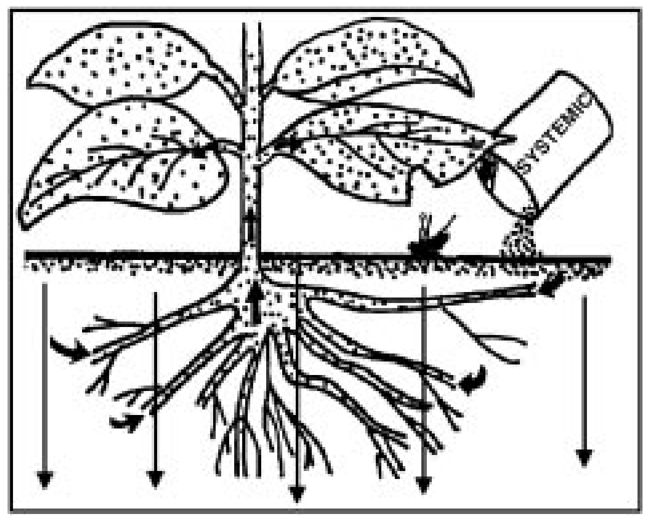

Figure 5. Water soluble pesticides leach more readily into ground water.

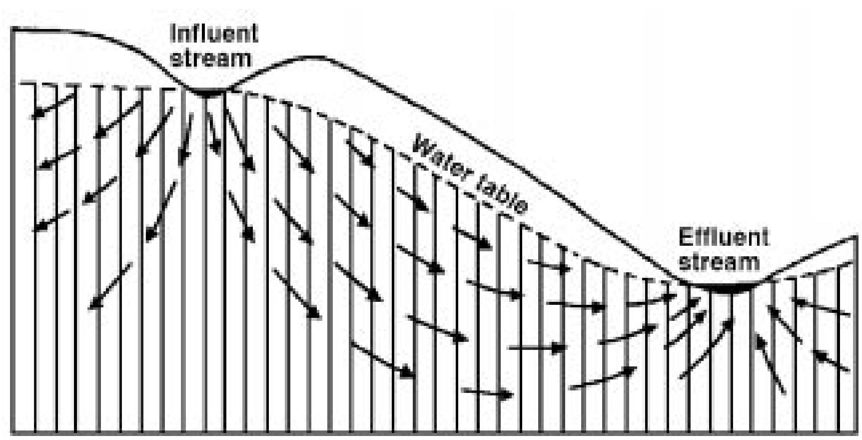

Figure 6. Percolation can transport water soluble pollutants from one body of water to another.

late the behavior of insects, other arthropods and nematodes. Insecticides include a wide variety of chemical compounds ranging from highly toxic nerve poisons to practically non-toxic pheromones.

Table 4 shows the four most used insecticides in the United States. Hundreds of others also have very wide use. Other pesticides that kill animals are the rodenticides for rodents, molluscicides for slugs and snails, piscicides for fish, avicides for birds, and predacides for predators. These are not as widely used as insecticides, but some of them have similar properties.

Table 4. Approximate volumes of the most widely used insecticides in the United States (U.S. Environmental Protection Agency, 1992.)

Insecticide	Usage in million pounds active ingredient (avg. 1991-1992)
Chlorpyrifos	15.0
Carbaryl	12.5
Malathion	12.5
Terbofos	10.0

Most insecticides applied to agricultural crops and in urban areas break down after a given time. However, some are very persistent and may remain in the environment for a long time. Persistence is a good quality for some insecticides, because it makes them effective in killing pests for a long time. However, persistent insecticides are more apt to find their way into water supplies at a level of toxicity that can cause problems. These substances can build up in invertebrates and fish. They can pass through the food chain to fish, birds, mammals, and even humans.

Insecticides have varying toxicity for aquatic organisms. Some can kill fish; some disrupt the food chain by killing aquatic insects and other organisms upon which fish depend for food. Table 5 shows the characteristics of several insecticides used in homes, gardens and agriculture. Some are general-use and others are restricted-use pesticides. Two restricted-use insecticides, aldicarb and oxamyl, have been reported in surface and ground water in several states.

Insecticide Leaching and Solubility

Several systemic insecticides that are applied to the soil are water soluble to allow them to be taken up through plant roots. Many of these are highly toxic to mammals. Table 6 shows some of the soil-applied systemic insecticides, their LD_{50}s and water solubility. Soluble systemic insecticides such as aldicarb and oxamyl are used at heavy rates (more than 10 pounds per acre) for nematode control. They persist for weeks, sometimes months, in the soil. Erosion can carry them into surface waters where they dissolve readily. Leaching can drive them into ground water. The EPA and the U.S. Geological Survey have reported their presence in ground water in several eastern states since the 1970s. Aldicarb was the first pesticide to be regulated by the EPA in an attempt to protect ground water.

Herbicides

Herbicides are among the most widely used chemicals in the U.S. They account for more than 70 percent of the total volume of pesticides applied in agriculture. Herbicides generally work by altering one or more of the following processes: seedling

Table 5. Common insecticides with their chemical properties and toxicity to fish (Environmental Protection Agency, 1992).

Insecticide	Solubility in runoff	Mobility in soil water	Half-life in days	Relative toxicity to fish[1]
Hydramethylnone	high	small	10	high
Diazinon	medium	high	30	high
Aldicarb	medium	high	>30	very high
Oxamyl	high	high	10	very high
Chlorpyrifos	high	small	30	very high
Malathion	small	small	1	very high
Acephate	small	small	3	very low
Carbaryl	medium	small	10	medium
Dimethoate	small	medium	7	medium
Trichlorfon	small	high	27	high
Dicofol	high	small	60	high
Propargite	high	small	56	high

[1]Fish toxicity based on catfish and bluegill. LC_{50} categories are rated as follows: very low = more than 100 mg/l, low = 10 to 100 mg/l, medium = 1 to 10 mg/l, high = 0.1 to 1 mg/l, very high = less than 0.1 mg/l.

Table 6. Some systemic insecticides leach into ground water because of their solubility, persistence, soil adsorption, rates of application, or widespread use. Weather, climate, precipitation and soil characteristics also can influence leaching.

Systemic insecticide common name	Solubility (ppm)	Toxicity (LD_{50}) (rat) in mg/kg	Persistence in the soil	Soil adsorption
aldicarb	6,000	0.9	medium	low
phorate	500	1	medium	medium
disulfoton	25	2	medium	medium
terbufos	15	4.5	medium	low
fenamiphos	25	6	medium	low
oxamyl	28	4	medium	low
imidacloprid	soluble	5,000	low	medium
carbofuran	351	4	medium	medium
acephate	650,000	1,447	low	medium

growth, transport of water and nutrients, production of plant foods (photosynthesis), plant cell development, and plant protein or lipid synthesis. Most herbicides are not very toxic to mammals.

The range of plants affected by a particular herbicide may be broad or very narrow. Some herbicides are toxic to almost all plants. These chemicals are appropriately named non-selective herbicides. Non-selective herbicides are useful for controlling vegetation along roadsides and railroad rights-of-way, on parking lots, or around petroleum storage facilities and electric power stations. Non-selective herbicides also can be used to control weeds when the physical characteristics of the target weeds are different from those of desirable plants nearby.

Many herbicides are designed to kill only certain plants. These are called selective herbicides. Most of the herbicides presently registered are selective, and they are used most widely in agriculture.

Selective herbicides may affect only a few weeds or a wide variety of plants. Most selective herbicides are very broad-spectrum plant killers. Some kill grasses and broadleaf plants and a few desirable plants. Others kill only broadleaf plants or only grasses. Some of the most highly selective herbicides kill only a single weed species, and only at one particular point in the plant's growth cycle. The usefulness of a selective herbicide lies not only in what it will kill, but also in what it will leave alive. One very broad-spectrum herbicide, clopyralid, is almost universally toxic to broadleaf plants, but does not affect seedling sugar beets.

The persistence of some herbicides can be looked upon as either a detriment or advantage. Obviously, the longer these materials remain active in the soil, the less appealing they are environmentally. However, to the farmer, weed control throughout the crop growing season (generally 3 to 6 months) is essential to ensure a good quality, profitable crop.

Sometimes the herbicide's active ingredient is not as toxic as its inert ingredients. Therefore, the formulation may have more impact on the toxicity of the product than the active herbicide ingredient. Table 7 gives properties of some common herbicides.

Herbicides in Surface and Ground Water

Herbicides vary widely. Some are water soluble enough to enter lakes or streams with rainfall or runoff irrigation water, but the hazard they represent depends on their persistence and interaction with the soil. They can also leach into ground water or move with eroding soil.

Many herbicides designed to be applied to emerged plants are inactivated once they reach the soil surface. Soil-applied herbicides, however, must be soluble in soil water in order to move into the root zones of target weeds. Some move deeply into the ground to kill deep-rooted perennials. Others don't move as deeply in order to kill shallow-rooted weeds and spare a deeper rooted crop.

Among the soil-applied herbicides that are taken up by plant roots are the triazines. Several of these have been detected in

Table 7. Characteristics of some commonly used herbicides, with relative toxicity to fish (U.S. Environmental Protection Agency, 1992).

Herbicide	Solubility in runoff	Mobility in soil water	Half-life in days	Relative toxicity to fish[1]
MSMA	high	high	100	very low
Benefin	high	low	30	very high
Dicamba Salt	low	high	14	low
2,4-D Amine Salt	low	medium	10	very low
MCPP Amine Salt	low	high	21	low
Pendimethalin	high	low	90	high
Glyphosate Amine Salt	high	low	47	very low
Metribuzin	medium	large	40	medium

[1]Fish toxicity based on catfish and bluegill. LC_{50} categories are rated as follows: very low = more than 100 mg/l, low = 10 to 100 mg/l, medium = 1 to 10 mg/l, high = 0.1 to 1 mg/l, very high = less than 0.1 mg/l.

surface and ground waters across the United States at levels near the MCL. Triazine herbicides are of particular concern to the EPA. Some triazines are very stable in the environment and may persist for long periods in the soil. The discovery of two widely-used triazines in surface and ground waters prompted the EPA to start a special review of all triazines in 1994. Table 8 shows some triazine herbicides, both those reported and not reported in U.S. waters.

Many triazines that have found their way into water supplies are important herbicides in corn. They are applied at the rate of several pounds per acre on millions of acres of corn. Studies show that the half-life of atrazine can exceed 170 days. Although simazine is not as soluble, it also has found its way into the nation's water supplies. Other, more soluble, triazines have not been found in ground water for reasons that include soil adsorption, short persistence, use patterns, and the depth of the ground water where they are used (Table 8).

Several other herbicides such as alachlor, diquat, glyphosate, picloram, and 2,4-D also have been detected in surface and ground water, and the EPA has assigned MCLs to all of them (Table 3).

Fungicides

Fungicides are used to control microorganisms. We could not feed this country without modern fungicides to control plant diseases. Moreover, toxic plant disease organisms would make food far more dangerous than fungicide residues at the maximum levels prescribed by the EPA. If you want to save your lawn, crops, garden or ornamental trees and shrubs, you must use fungicides.

Fungicides are of small concern in protecting water quality. They are used less frequently than other pesticides, and most are not persistent. However, they can be a possible source of pollution if applied, stored or disposed of improperly. Even when applied correctly, these substances can drift away from the application area, leach into ground water and be carried away by runoff. Table 9 lists some fungicides commonly used by homeowners and farmers, and in industry. Fungicides are seldom found in water, with the exception of some of the heavy metal fungicides that contained mercury. The EPA has cancelled most

Table 8. The solubility, persistence and soil adsorption characteristics of triazines.

Triazines - common name	Solubility (ppm)	Persistence (half-life)	Soil adsorption
metribuzin	1,200	medium	medium
promoton	620	high	low
hexazinone	330	medium	medium
ametryn	185	low	medium
atrazine	33	high	low
prometryn	33	medium	medium
cyanazine	16	low	medium
simazine	3.5	high	low

Table 9. Risk factors of some commonly used fungicides.

Fungicide	Hazards
Mancozeb	Cancer (Ethylenethiourea)
Thiram	Nerve poison, birth defects
Benomyl	Birth defects
Thiophanate	Mutations, birth defects
Pentachloronitrobenzine	Accumulates in food chains, hormone effects
Phenyl mercuric acetate	Heavy metal poisoning
Fixed Copper	Toxic to plants and phytoplankton
Kitazin-P	Nerve poison
Streptomycin	Allergic reaction

uses of these fungicides. When using a fungicide, always follow instructions on the label to minimize the risk of water pollution.

Soil Fumigants and Ground Water

Soil fumigants are gaseous chemicals applied to the soil to control various pests such as plant disease organisms, insects and weed seeds. They are nonselective, and many are toxic to all life forms. They have various chemical properties. Fumigants are very nonpersistent. They last from a few days to a few weeks after application. With the exception of metam-sodium, most are only slightly soluble in water. Fumigants can move rapidly through the soil-gas interface and can dissolve in various amounts in soil water. The same factors that affect insecticides and herbicides also govern the movement of soil fumigants into ground and surface waters.

Soil fumigants such as ethylene dibromide, dibromochloropropane, metam-sodium and dichloropropane have been detected in ground and surface waters. The chlorinated fumigants can produce serious chronic effects at low concentrations, and the EPA has assigned them very low MCLs (Table 3).

Soil fumigants are usually applied at much higher rates than other pesticides. Rates of several hundred pounds per acre are common. Most of this use occurs in California, Florida and Texas. Residues of dibromochloropropane in California's ground water influenced EPA to cancel that product. Dichloropropene also has been detected in ground water in the San Joaquin Valley of California. In October, 1996, the EPA levied heavy fines against an Idaho company for misapplication of the fumigant metam-sodium which caused contamination of the Snake river.

Water Quality Protection

Most water pollution does not come from the normal, correct usage of pesticides. Problems arise from misuse or careless handling. Here is a checklist to use when applying any pesticide. These guidelines can help safeguard the future of our water quality.

- Read all product labels and follow label directions.
- When possible, use pesticides and fertilizers with less potential for surface runoff or leaching.
- Use integrated pest management (IPM) tactics to control pests, using pesticides only when necessary.
- Don't apply pesticides when conditions are most likely to promote runoff or excessive leaching.
- Have soil tested to determine the fertilizer needs of a given crop.
- Store potential water pollutants away from water sources such as wells, ponds and streams.
- Don't spray pesticides on a windy day (wind more than 4 mph).
- Calibrate all pesticide application devices to ensure that the correct dosage is being applied.
- Prevent pesticide spills and leaks from application equipment.
- Make sure product containers do not leak.
- Do not dispose of leftover materials by dumping them in drains or on the ground. Dispose of pesticides according to label directions.
- Use low-toxicity products when a choice is possible.
- Use narrow spectrum products when a choice is possible.
- Prevent back flow during mixing operations by maintaining an air gap between the water fill hose and the water level in the spray tank

- Always mix, handle and store pesticides down slope from and at least 150 feet from water wells.
- Consider the vulnerability of the site; be sure that weather and irrigation won't increase the risk of water pollution.
- Evaluate the location of water sources.
- Leave buffer zones around sensitive areas such as wells, irrigation ditches, ponds, streams, drainage ditches, septic tanks, and other areas that lead to ground or surface water. Don't apply pesticides in these locations.
- If you use a spray system hooked to your hose, use a backup nozzle on your house connection to prevent pesticides from flowing back into your home water system.
- Use up pesticides on your shelf before buying more.
- Use up older pesticides before they exceed their shelf life.
- Do not water pesticide-treated areas immediately after application unless indicated on label instruction. Runoff could carry pesticides into storm drains that empty into lakes, rivers or streams.
- Do not use banned or canceled pesticides. Such materials should be stored safely until a hazardous waste disposal event is organized in your community.

Glossary

Adsorption - The adhesion of materials to the surface of a solid.

Bioaccumulation - The storage or accumulation of materials in the tissues of living organisms.

Broad spectrum - A pesticide that will control a wide variety of organisms.

Carcinogenic - A property that makes a material more likely to cause cancer in humans or animals that are exposed to it.

Efficacy range - How many or how few organisms a pesticide will control.

Ground water - A region within the earth that is wholly saturated with water.

Inert - A substance that is not reactive in the environment and does not contribute to the action of the active ingredient. Inert materials often function as carriers and dilutors of active ingredients.

Leaching - Dissolving and transporting of materials by the action of percolating water.

Narrow spectrum - A pesticide that will control only a few organisms.

Non-selective - A pesticide that will kill or control both target pests and desirable organisms.

Non-target - An organism towards which an application is not directed.

Persistence - The ability of a substance to remain in its original form without breaking down.

Pesticide - A material used to kill an unwanted pest.

Selectivity - The ability of a pesticide to control target pests but not desirable or beneficial crops and organisms.

Solubility - The ability to be put into solution.

Target pest - An unwanted species toward which a pesticide application is directed.

Target weed - An unwanted weed species toward which an herbicide application is directed.

Toxic - Poisonous to an organism with which it comes in contact.

Toxin - A substance that is poisonous to a given organism.

Water pollution - A detrimental change in the chemical or physical properties of water.

Water table - the upper limit of the saturated level of the soil.

References

Adams, C.D., and Thurman, E.M. 1991. Formation and transport of deethylatrazine in the soil and vadose zone. *Journal of Environmental Quality.* 20:540-547.

Cuello, C., *et al.* 1976. Gastric cancer in Colombia I. Cancer risk and suspect environmental agents. *Journal of the National Cancer Institute.* 57(5): 1015-1020.

Dorsch, *et al.* 1984. Congenital malformations and maternal drinking water supply in rural South Australia: A case control study. *American Journal of Epidemiology.*119(4): 473-486.

Eardley, A.J. 1965. Ground Water. *General College Geology.* Harper & Row. New York, N.Y. pp. 148-169.

Farm Chemicals Handbook '95. 1995. Meister Publishing Co., Willoughby, Ohio.

Gosselin, R.E., H. C. Hodge, R.P. Smith and M.N. Gleason. 1976. *Chemical Toxicity of Chemical Products.* The Wilkins & Wilkins Co., Baltimore, Md.

Knox, E.G. 1972. Anencephalus and dietary intakes. *British Journal of Preventive and Social Medicine*. 26:219-223.

Mills, M.S. and Thurman, E.M., 1994. Reduction of nonpoint-source contamination of surface water and ground water by starch encapsulation of herbicides. *Environmental Science and Technology.* 28: 73-79.

Molihagen, Tony, Lloyd Urban, R. Heyward Ramsey, A. Wayne Wyatt, Don McReynolds and J. Tom Ray. 1993. *Assessment of Non-Point Source Contamination of Playa Basins in the High Plains of Texas.* Water Resources Center, Texas Tech University.

Moon, T.J., P.B. Mann and J.H. Otto. 1956. *Modern Biology.* Henry Holt and Company, New York, N.Y.

National Research Council. Board on Agriculture. 1993. *Soil and Water Quality: An Agenda For Agriculture.* National Academy Press, Washington, D.C.

National Academy of Sciences, Safe Drinking Water Committee. 1977. *Drinking Water and Health.* Washington, D.C.

NRDC. (Natural Resources Defense Council). 1994. *Think Before You Drink: 1992-93 Update.* Washington, D.C.

Paterson, K.G. and J. L. Schnoor. 1992. Fate of Alachlor and Atrazine in Riparian Zone Field Site. *Research Journal of the Water Pollution Control Federation.* 64:274-283.

SIPRI (Stockholm International Peace Research Institute). 1973. J.P. Robinson, C.G. Heiden and H. von Schreeb, eds. *CB Weapons Today.* Humanities Press, New York, N.Y.

Squillace, P. J., E.M. Thurman and E.T. Furlong 1993. Groundwater as nonpoint-source of atrazine and deethylatrazine in a river during base flowconditions: *Water Resources Research.* 29(6): 1719-1729.

Stiegler, J.H., J.T. Criswell and M.D. Smoten. *Pesticides in ground water.* OSU Extension Facts, No. 7459: 1-4.

Terry, et al. 1995. *Commercial Fertilizers 1995.* The Association of American Plant Food Control Officials/The Fertilizer Institute. Washington, D.C.

Texas Agricultural Extension Service. 1993. Pesticide Use Survey Database.

Texas Agricultural Extension Service. 1993. *Pesticide Applicator Training, General Manual, Commercial/Noncommercial.* B-5056.

Texas Agricultural Extension Service. 1993. *Structural Pesticide Applicator Training, General Manual, Commercial/Noncommercial/Technician.* B-5073.

Thomas, H.E. 1955. Underground sources of our water. *Water, The Yearbook of Agriculture.* United States Department of Agriculture.

United States Office of the Federal Register. 1995. *Code of Federal Regulations, Title 40 part 143, Drinking Water.*

United States Environmental Protection Agency. 1990. *The quality of our nation's water: A summary of the 1988 national water quality inventory.* EPA Pub. No.440/4-90-005.

United States Environmental Protection Agency. *1992. Pesticide industry sales and usage, 1990 and 1991 market estimates*. EPA Pub. No. 733-K-92-001.

Ware, G.W. 1992. *Reviews of Environmental Contamination and Toxicology.* Springer-Verlag, New York, N.Y.

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