G3213

PESTICIDES IN GROUNDWATER

How They Get There
What Happens to Them
How to Keep Them Out

Gary Jackson, Bruce Webendorfer, Byron Shaw, and John Harkin

Groundwater is important to the economic and physical well-being of the people of Wisconsin. It provides nearly 70 percent of the state's drinking water and is the major source of water for most industry and agricultural irrigation. Like lakes and streams, groundwater can be polluted by human activities. The many possible sources of pollutants include mining, landfills, septic systems, livestock waste storage facilities, fertilizers, pesticides and the spreading of municipal, agricultural and industrial wastes on the land. Pesticides and other hazardous substances sometimes move down through the soil into groundwater, posing a potential health risk for both humans and domestic animals that drink the water.

How Pesticides Get into Groundwater

Groundwater and surface water are interrelated. In fact, they are parts of the same natural "plumbing" system called the hydrologic cycle.

Water that falls on the earth's surface as rain or snow runs off into lakes and streams, evaporates, or soaks into the soil. Some of the water that enters the soil is taken up by plant roots and some gradually seeps downward, filling spaces and cracks in the underlying layers of soil, gravel and rock. The water in these deep, saturated layers is the groundwater.

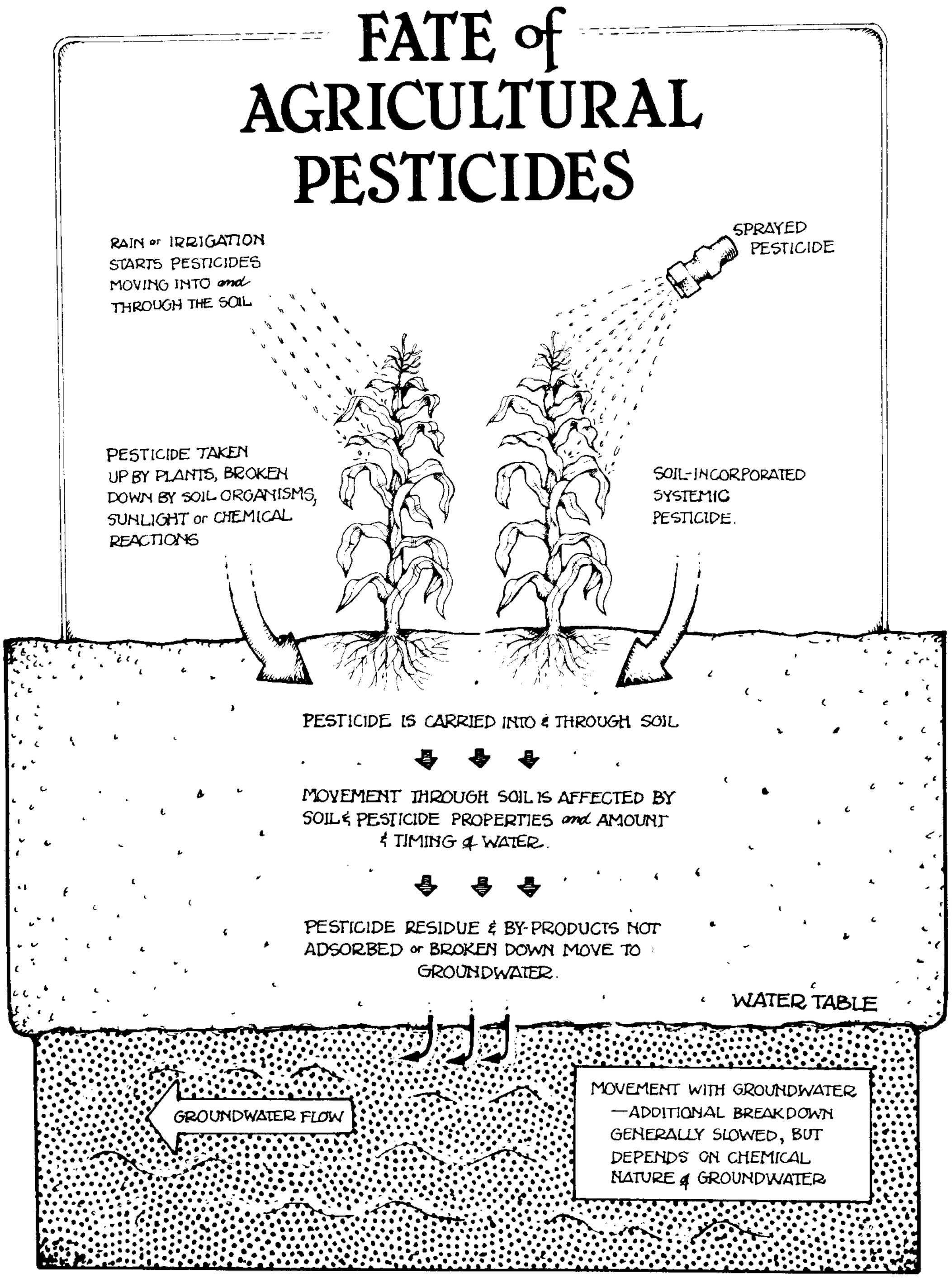
The water seeping down through the soil can carry with it water-soluble nutrients, minerals, and other substances in or on the soil. This "leaching" process is similar to what happens when you make drip coffee. Water drips through the ground coffee leaching caffeine and flavoring compounds into the coffee pot. But unlike making coffee, the leaching of pesticides through the soil is unintentional and the amounts are so small that they can only be detected by sophisticated laboratory analysis of the water.

Whether pesticides that leach into the groundwater pose a hazard to humans or animals depends on the toxicity and concentration of the compounds and how they "degrade" or break down as they move through the soil. In time, pesticides break down into simpler chemical compounds. The breakdown can be caused by reaction with minerals and other natural chemicals in the soil or water, by physical factors such as sunlight or heat, or by bacteria and other microorganisms. The compounds eventually resulting from the breakdown process are usually nontoxic, although some compounds formed in intermediate steps in the process can themselves be toxic.

For a pesticide to leach into groundwater and present a hazard, then, it must move down through the soil and it must resist breakdown to nontoxic compounds. This is generally not a common occurrence and depends on three things:

—the nature of the soil,
—the nature of the pesticide
—the amount and timing of water applied to the soil through precipitation, irrigation, or a combination of the two.

All three factors work together in a complex way to determine the movement and breakdown of pest icicles in the soil. Figure 1 summarizes the process of movement and breakdown.



The Soil

Soil characteristics are very important in determining how a pesticide breaks down and whether it leaches into groundwater. Because most breakdown occurs in the soil, there is a greater potential for groundwater contamination in areas where substances such as pesticides move quickly through the soil. Sandy soils have large “pore” spaces between individual particles, and the particles provide relatively little surface area for “sorption,” or physical attachment of pesticides. Large amounts of rainfall or excessive irrigation water can percolate through these soils, and dissolved pesticides can move rapidly down through the soil and into groundwater. Clay soils, on the other hand, are made up of extremely small particles that provide a vast surface area for sorption. The small pores between clay soil particles slow the movement of water and dissolved pesticides through the soil.

While held securely to soil particles, pesticides are kept from moving to groundwater and are more likely to be broken down. Breakdown occurs through reaction with the mineral constituents of the soil, with the natural chemicals dissolved in the soil moisture, or by the action of bacteria and fungi in the soil. Most of this chemical and biological breakdown takes place in the loose, cultivated surface layers, where the soil tends to be warm, moist, high in organic matter, and well-aerated.

Soil organic matter is also important in preventing pesticide movement and promoting pesticide breakdown. Organic matter provides additional surface area for sorption and provides an excellent environment for chemical and biological breakdown to occur. Soil moisture and temperature also affect pesticide breakdown. Breakdown is slower in drier soils and at lower temperatures because both chemical and microbial reactions are slower under these conditions.

The Pesticide

The characteristics of the pesticide itself also affect both how it moves through the soil and how it breaks down. Different pesticides have different abilities to adhere or “sorb” to soil particles. Some pesticides stick very tightly to soil grains, much like wax sticks to the paint on a car; others stick only loosely, like dust, and are easily dislodged; still others stick a little harder, like caked-on-mud, but can be dislodged with enough water, as in a car wash.

Equally important, pesticides and their interim breakdown products differ in their ability to dissolve in water. Pesticides that are very soluble in water and poorly sorbed can move through the soil to the groundwater much more easily than pesticides that are not very soluble and strongly sorbed by soil particles.

Many pesticides applied as sprays to the leaves of plants are insoluble in water. Particles that remain sticking to the plant leaves, or that fall off or are washed or blown off and land on the soil surface, may be broken down by ultraviolet light from the sun in a process called photolytic decomposition—degradation by sunlight.

Pesticides vary greatly in their rates of breakdown. The inorganic pesticides used more commonly many years ago, such as sulfur dust, copper, mercury, and arsenic compounds, change very slowly in the soil and do not really break down. However, these pesticides are not used much any more and are seldom leached from the soil because they are so insoluble and strongly sorbed. Virtually all modern pesticides are made from synthetic chemical compounds. These pesticides break down more rapidly than the older compounds, but differ among themselves in their solubilities, sorption characteristics and rates of breakdown.

For example, insecticides are usually grouped into three broad chemical classes: chlorinated hydrocarbons, such as DDT, aldrin, dieldrin and chlordane; organophosphates, such as phorate (Thimet), fonofos (Dyfonate), terbufos (Counter), disulfoton (Disyston), malathion and parathion; and carbamates, such as carbofuran (Furadan), aldicarb (Temik) and oxamyl (Vydate). Organophosphate and carbamate insecticides are easily broken down through the action of chemicals and microbes in the soil. They generally break down more rapidly than chlorinated hydrocarbon insecticides. However, chlorinated hydrocarbon insecticides are generally less water-soluble and much more strongly sorbed onto soil particles.

In evaluating the potential for a pesticide to leach to groundwater, it is important to consider the volubility and sorption characteristics of the pesticide and its breakdown products.

The Amount and Timing of Watering

The movement and breakdown of pesticides in the soil can be affected by the amount and timing of water applied to a field, whether the watering occurs naturally by rainfall, artificially by irrigation, or by a combination of both.

Both soil moisture and temperature can affect the chemical breakdown of a pesticide. If cold rain or irrigation water cools the soil, breakdown reactions can be slowed. It can also wash pesticides off plants and into the soil, removing them from sunlight which might otherwise promote breakdown. Too much water can leach water-soluble pesticides beyond the reach of plant roots, resulting in a loss of crop production and surface water or groundwater contamination.

Excess moisture also causes problems with soil-incorporated, granular systemic pesticides. These pesticides are combined with a carrier granule—usually made from clay, corn cobs or nut shells—and placed directly into the soil. The pesticide within the granule must dissolve in the soil moisture before it is taken up through plant roots and distributed throughout the entire plant. During the growing season, too much rain and irrigation can leach the pesticide through the soil to the groundwater. Systemic pesticides currently in use are designed to decompose in the soil and in plants by the end of the growing season, but this does not always happen. Any residues not taken up by plants, sorbed to soil particles or broken down during the growing season can be leached through the soil by heavy rains in the fall, winter or early spring. The goal in using such pesticides with irrigation, then, is to add enough moisture to the soil to assure good plant growth and pesticide uptake, but not so much as to wash pesticides down below the reach of plant roots and into the groundwater.

What Happens to Pesticides Once They Are in Groundwater

Pesticides continue to break down in groundwater, but for lack of light, heat and oxygen in the water-saturated layers below the surface, chemical breakdown is generally much slower than in the surface layers of the soil.

In Wisconsin and other northern states, groundwater close to the soil surface is colder than deeper groundwater during the winter, but warmer during the summer. For example, in an area where the water table is close to the ground surface, groundwater 5–10 feet from the surface might drop to 39-41° F at the coldest part of the winter and rise to 59-61° F at the hottest part of summer. Yet, groundwater 10–15 feet below the water table would have a constant temperature of 50–53° F throughout the year. The relatively constant temperature of deeper groundwater throughout the year probably allows a constant, if slow, rate of breakdown. During the months when the soil is not frozen, coarse soils that allow water to pass through easily might also allow oxygen and in extreme cases soil bacteria to pass through to shallow groundwater, where slow microbial breakdown could go on. Breakdown is slowest in deeper levels of groundwater, where oxygen and bacteria are either totally absent or present only at very low levels.

Groundwater does not remain stationary, but moves vertically and horizontally in response to gravity and hydraulic pressure. Groundwater “flow” rate is frequently only several feet per year, although in permeable sand and gravel aquifers, such as those found in central Wisconsin, groundwater can move one or two feet per day. Even at this “fast” rate, groundwater and substances dissolved in it might take 15 years to move only one mile. Because the movement of groundwater is slow and difficult to predict, substances that enter the groundwater in one location can unexpectedly turn up years later in different locations.

It is not easy to purify groundwater that has become contaminated. Treatment of groundwater with filters on domestic taps, for example, can be expensive and is not always entirely successful. The best policy is to keep hazardous substances out of groundwater in the first place.

Avoiding Future Problems of Pesticides in Groundwater

The only sure way to avoid contaminating groundwater with pesticides is not to use them, but farmers have few practical alternatives to some of these substances. On the other hand, applying a pesticide should not be viewed as the only possible solution to a pest problem. Pest control methods should be selected to achieve effective, practical, economical and environmentally sound control. The last of these considerations is as important as the first three, and protecting groundwater is an important part of environmentally sound pest management.

While chemicals are generally components of any pest control program, other methods or combinations of methods might sometimes be more appropriate. In recent years, attention has been directed toward the coordinated use of multiple methods of pest control, an approach known as Integrated Pest Management (IPM). In an IPM program, all available techniques for pest control are considered and pesticides are used only when necessary.

When pesticides are used, the potential for groundwater contamination can be minimized if applicators follow label directions, use irrigation scheduling, and follow handling, storage and disposal guidelines.

The pesticide label reflects the best scientific knowledge on the safe and environmentally sound use of the pesticide. The label dictates how and on what crops the pesticide is to be applied, who can apply it, how it should be stored and transported, and how the empty container is to be disposed of.

Irrigation scheduling increases irrigation efficiency and minimizes leaching of water and pesticides. The Wisconsin *Irrigation Scheduling Program* (WISP) has been used successfully by Wisconsin growers to plan irrigation, reduce water use and maintain crop productivity. There are hand and computerized versions of WISP. Information on both is available through county Extension offices.

Improper disposal of pesticide containers, careless storage, and spills during mixing and loading operations have caused groundwater contamination in Wisconsin. Farmers and commercial applicators using restricted-use pesticides are required to take a pesticide applicator training course conducted by University of Wisconsin-Extension. The course provides guidelines for safe storage, handling and disposal of pesticides and pesticide containers. Careful attention to the guidelines will protect groundwater and the applicator's safety.

Yet even with careful handling and application of pesticides, unforeseen problems can still occur. What happens then? Comprehensive state groundwater protection legislation enacted in 1984 established procedures for addressing groundwater contaminantion. Under the law the Department of Natural Resources adopts numerical standards for substances, including pesticides, with potential to contaminate groundwater. "Enforcement standards" are specific contaminant levels that cannot legally be exceeded. "Preventive Action Limits" (PAL) are set at a percentage of the enforcement standard. When a PAL is exceeded, state regulatory agencies are required to take action to lower the contaminant concentration and prevent further contamination.

The Wisconsin Department of Agriculture, Trade and Consumer Protection (DATCP) establishes and enforces regulations on pesticide use. When a pesticide exceeds a PAL, DATCP must take additional regulatory action. Actions can include changing label directions to reduce application rates, restricting use in some areas or on some crops, banning use of the pesticide, or other actions to prevent further contamination.

Groundwater is one of Wisconsin's most important natural resources. It provides a vast supply of clean water for use in agriculture, homes and industry. We can ensure high quality groundwater in the future only if we manage the resource wisely now. The best way to protect groundwater is to understand its nature and workings and how human activities, including the use of pesticides, can affect this valuable resource.

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