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Fate of pesticides in soil

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Quick Facts

Pesticides applied to protect plants from disease, weeds and insect damage usually come into contact with soil, where they undergo a variety of transformations.

Pesticides disappear from soil at varying rates depending on their chemical properties, soil and weather conditions.

Pesticide decomposition results from microbial, chemical and photochemical processes. Decomposition by soil microorganisms usually is the most important.

Some pesticides or their degradation products accumulate in soil and move downward into ground water.

Pesticides are widely used to control pests that affect agricultural crops and pests in homes, yards and gardens. These chemicals, classified for the kinds of pests they control, include insecticides, herbicides, fungicides, nematocides, rodenticides, miticides, and soil fumigants.

Pesticides generally are man-made organic compounds. Some are selective, against a given pest (target organism), while others are relatively non-selective, toward a large group of organisms. Some examples of non-selective pesticides are Roundup (glyphosate), a herbicide used to kill many types of plants, and parathion, which acts against a broad spectrum of insects. In some cases, pesticides used for plant protection may be applied to soil before planting, while in others, the application is made after seeding. Usually, most of the applied chemical comes into contact with soil. Application is by spraying a liquid, broadcasting granular formulations, or fumigation.

Concerns about environmental and health issues related to pest control make it important to understand the possible hazards associated with their use and to minimize risks.

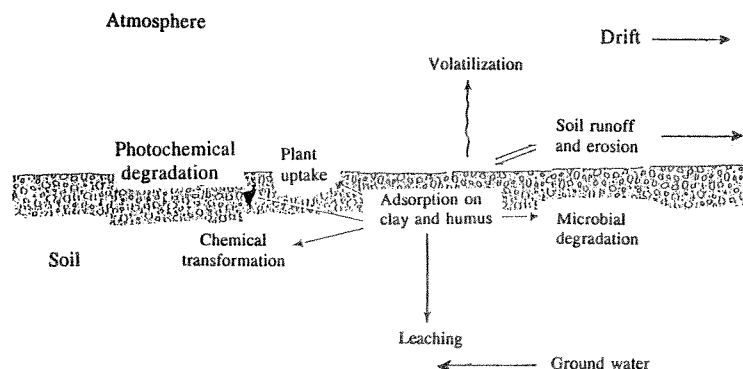


Figure 1: Fate of pesticides in soil.

Soil Persistence

The fate of pesticides in soil is controlled by chemical, biological and physical forces. In Figure 1, various processes contribute to the disappearance of these compounds from soil. When decomposition (degradation and transformation) occurs, the chemical structure of the pesticide changes. The downward movement of pesticides through the plant rooting zone of soil reduces their concentrations in the surface soil but may ultimately lead to ground water contamination. The uptake of pesticides by plants, microorganisms and animals (absorption or bioabsorption) likewise removes these chemicals from soil. Absorbed pesticides are stored in the tissue of organisms, a process called bioaccumulation, or transformed by enzymes of the organisms.

Pesticides remain or persist in soil for a limited time. Persistence time, which relates to the rate of disappearance, varies from days to years depending on the type of pesticide, soil moisture, organic matter, temperature and pH. Relative persistence times for a variety of compounds are shown in Table 1. In general, non-persistent pesticides disappear from soil in less than one month, while moderately persistent chemicals take from one to three months. Persistent

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pesticides are present for many months (years in some cases) after application. Persistence may differ considerably because of varying environmental conditions and application rates.

Chemical and Photochemical Degradation

Most pesticides are chemically stable across a broad range of conditions, but a few degrade spontaneously because of their lack of stability in soil. For example, the herbicides Treflan and atrazine are subject to chemical decomposition.

The process of photodegradation involves the chemical transformation of substances under the action of sunlight. Pesticides susceptible to photodegradation include: 2,4-D, Treflan, Banvel (dicamba) and parathion. Photochemical reactions are limited to the soil surface. Consequently, once pesticides are incorporated into soil, they are protected from photochemical transformation.

Degradation by Soil Microorganisms

The principal reason for the disappearance of most pesticides from soil is microbial decomposition. Common soil bacteria and fungi can degrade the majority of these compounds. Those chemicals that decompose slowly or incompletely by microorganisms, such as the herbicide Tordon (picloram), show long persistence times. On the other hand, 2,4-D disappears quickly because it degrades by a variety of common soil microorganisms. Usually as microorganisms carry out degradation, they obtain carbon and energy that they require for growth. An increase in the size of the pesticide-degrading populations leads to faster rates of degradation.

Most pesticides transform to simple, non-toxic products such as carbon dioxide and water. A few, however, convert to chemically complex products that can accumulate in the environment; for example, atrazine (2-chloro-4-ethylamino-6-isopropylamino-s-triazine) converts to deethylatrazine (2-amino-4-chloro-6-isopropylamino-s-triazine). Some pesticides are resistant to microbial decomposition because they are toxic to microorganisms or do not support their growth.

The most important soil factors that influence biodegradation are temperature, moisture, presence or absence of oxygen (O_2), organic matter, and clay content. If soil is cold (below 50°F [10°C] or dry, microbial activity is slow and degradation is limited. Some microorganisms function best under aerobic conditions, while others are most active in the absence of oxygen. Microbial abundance and activity are stimulated by the addition of organic materials to soil. This usually results in faster rates of pesticide degradation. Certain pesticides bond to the surfaces of organic particles (humus colloids) and clay minerals. This process, adsorption, limits the

access of microorganisms to the pesticides and slows the rate of decomposition. Microbial degradation occurs most rapidly in warm, moist soil that contains readily decomposable organic matter such as manure or fresh plant material.

Uptake by Higher Organisms

Some pesticides must be taken up by plants, insects or other target organisms in order to be effective. Pesticides also are taken up by non-target organisms through root or leaf absorption by plants and ingestion or contact by animals. Once inside the tissue of an organism, they are transformed by the action of enzymes or stored in an unchanged state. Pesticide degradation within the plant is an important mechanism of detoxification. It helps reduce the hazard of residues in food.

Aerial Movement

Pesticide movement from soil to the atmosphere and atmosphere to soil occurs under many conditions. With aerial application, winds can carry the pesticide outside the target area. It may return to the Earth's surface at places far from the point of application. Pesticides move from soil into the atmosphere by volatilization and wind erosion. Not all pesticides are subject to volatilization, but for a few, this is a major pathway of loss from soil. Among the more volatile herbicides are 2,4-D (butyl ester form), Treflan (trifluralin), and Tordon (picloram). Volatilization within a few hours after application can be substantial under warm and windy conditions but often can be reduced by incorporation of pesticides into soil.

Leaching and Run-off

Excessive rain or irrigation can cause pesticide leaching. Water that moves down through soil or through cracks and worm tunnels transports water soluble substances. The herbicides 2,4-D and Tordon are leached easily in soil. Chemicals, such as paraquat, that are strongly absorbed onto clay and humus show limited downward movement. The leaching of pesticides can contaminate ground water.

Pesticides also move by run-off and erosion. Such movement most likely occurs on sloping land during periods of intense rain or excessive irrigation. This can lead to contamination of lakes and other surface water.

Ground Water Contamination

Traces of some pesticides were detected recently in surveys of subsurface waters across the U.S. Among the chemicals found were Temik (aldicarb), Lasso (alachlor), malathion, and Tordon. In Colorado, atrazine was reported in subsurface water. For the most part, pesticide concentrations in ground water have been lower

than the health advisory limits set by the U.S. Environmental Protection Agency. However, the concentrations of diazinon, chlordane and a few herbicides exceeded these limits at certain locations.

Ground water contamination occurs from point and non-point sources. Point-source contamination results from an identifiable event such as a pesticide spill. Spills and other mishaps that occur during transport, handling, mixing, and application contribute to point source contamination. Accidents around wells and water supplies are of special concern with regard to effects on ground water.

Pollution that results from non-point sources cannot be traced back to a specific location or event. For example, ground water contamination can result from the leaching of pesticides applied to fields and gardens. The potential for this problem varies with the type of pesticide, soil characteristics, management practices (irrigation), and precipitation patterns. The greatest risk to ground water quality exists where water tables are close to the soil surface and with soils that are sandy and low in organic matter. Pesticides found in subsurface water generally are those that are mobile and persistent.

References

- Bohmont, B.L. 1990. The Standard Pesticide User's Guide. Prentice Hall, Englewood Cliffs, NJ.
- Marer, P.J., M.L. Flint and M.W. Stimmann. 1988. The Safe and Effective Use of Pesticides. University of California, Statewide Integrated Pest Management Project. Division of Agriculture and Natural Resources. Publication 3324. Oakland, CA.

Table 1. Relative Persistence¹

Pesticide ²	Type ³	Persistence ⁴
Ally (metsulfuron)	H	P (at high pH)
Ambush (permethrin)	I	N
Amiben (Chloramben)	H	N
Amitrole T (amitrole)	H	N
(atrazine)	H	P
Banvel (dicamba)	H	N
Benlate (benomyl)	F	P
Betanex (desmedipham)	H	N
Bladex (cyanazine)	H	N
Bravo (chlorothalonil)	F	M
Counter (terbufos)	I	N
Cytrole (amitrole)	H	N
2-4, D	H	N
(diazinon)	I	M
Di-Syston (disulfoton)	I	N
Dowpon (dalapon)	H	N
Dual (metolachlor)	H	M
Dyfonate (fonofos)	I	M
Eptam, Eradicane (EPTC)	H	N
Furadan (carbofuran)	I	M
Glean (chlorsulfuron)	H	P
Lasso (alachlor)	H	N
Lorsban (chlorpyrifos)	I	M
(malathion)	I	N
Nortron (ethofumesate)	H	M
(paraquat)	H	P
(parathion)	I	N
Poast (sethoxydim)	H	N
Princep (simazine)	H	P
Prowl (pendimethalin)	H	M
Ramrod (propachlor)	H	N
Ro-Neet (cycloate)	H	N
Roundup (glyphosate)	H	M
Sencor (metribuzin)	H	M
Sevin (carbaryl)	I	N
Sonalan (ethalfuralin)	H	M
Sutan (butylate)	H	N
Temik (aldicarb)	I	M
Thimet (phorate)	I	N
Tordon (picloram)	H	P
Treflan (trifluralin)	H	M

¹Information source: 1991 Colorado Pesticide Guide — Field Crops. Colorado State University Cooperative Extension, Publication XCM-45.

²A manufacturer's product name is given first followed by the common name (in parenthesis). Some compounds are sold under more than one name. Where a pesticide is marketed under several names, only the common name is given.

³F=fungicide; H=herbicide; I=insecticide
P=persistent; M=moderately persistent;
N=non-persistent