

# NATURAL RESOURCES

## CORNELL COOPERATIVE EXTENSION

### Pesticides: Health Effects in Drinking Water

by Nancy M. Trautmann and Keith S. Porter

Center for Environmental Research

and Robert H. Wagenet

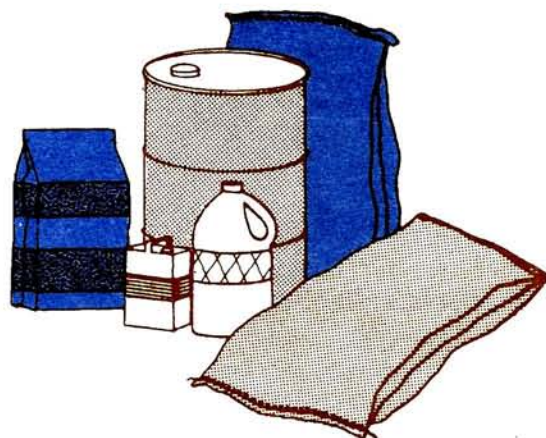
Dept. of Agronomy  
Cornell University

Traditionally, groundwater has been assumed to be a relatively pristine source of water, cleaner and better protected than surface water supplies. Although nitrate and bacterial contamination were known to occur in some locations, groundwater was thought to be immune from more serious forms of pollution such as industrial discharges, hazardous waste dumps, or leaching of pesticides from agricultural operations. Within the past decade, however, a variety of synthetic organic compounds have been discovered in the nation's groundwater, often at concentrations far exceeding those in surface water supplies.

Synthetic organic compounds are chemicals synthesized from carbon and other elements such as hydrogen, nitrogen, or chlorine. They do not occur naturally, but are manufactured to meet hundreds of needs in our daily lives, ranging from moth balls to hair sprays, from solvents to pesticides. Why have they only recently been discovered in groundwater? One reason is that use of synthetic organic compounds has greatly increased within the past 40 years, and some of these gradually have made their way into groundwater. Another reason for the recent discoveries of organic contaminants in groundwater is that the laboratory capability to detect these chemicals has greatly improved within the past decade. A classic example of this occurred in Bedford, Massachusetts, where severe organic chemical contamination of the town groundwater supply was discovered in 1978 only because a resident engineer took a sample of his home tap water with him to work where he was developing and testing a new laboratory instrument for analyzing organic chemicals. A total of nine toxic organic compounds were discovered in this drinking water sample, resulting in permanent closure of the town's water supply wells. The Bedford contamination eventually was traced to several local industries that were improperly disposing of their chemical wastes.

Now that people are aware of organic contaminants in drinking water, sampling for such chemicals has increased, and more than 700 synthetic organic compounds have been identified in various U.S. drinking water supplies. This contamination originates from a variety of sources, including household products and leakage or improper disposal of chemical wastes from commercial and industrial establishments. By-products of industrial manufacturing or cleaning operations have been disposed of in unrecorded dumpsites across the nation, and some of these chemicals have leached to groundwater. Pesticides constitute another, smaller category of synthetic organic compounds, some of which have been found in groundwater.

Between 1950 and 1980 production of synthetic organic pesticides more than tripled in the United States, from about 400 million pounds in 1950 to over 1.4 billion pounds in 1980. Although



most of these compounds have not been detected in groundwater, a few have become significant contaminants. Twenty-two pesticides have been detected in U.S. wells, and up to 80 are estimated to have the potential for movement to groundwater under favorable conditions. One area with conditions highly conducive to leaching is Long Island, New York, where soils are sandy, the water table is shallow, and agriculture is intensive. A total of 13 pesticides have been detected at least once in Long Island groundwater, and 8 of these have been found multiple times through continued monitoring. In upstate New York, sampling for pesticides has been limited to measurement of aldicarb in wells near treated fields. Low concentrations of aldicarb have been detected in 30 percent of the 76 wells sampled. Twenty-two other states, including Maine, Maryland, and New Jersey, also have reported some pesticide contamination of groundwater.

This bulletin focuses on the health effects of pesticides in drinking water, although the same concepts also apply to the much wider range of synthetic organic compounds contaminating groundwater supplies.

### Types of Pesticides in Groundwater

The health effects of pesticides depend upon their chemical characteristics. Before the 1940s most pesticides were compounds of arsenic, mercury, copper, or lead. Although these compounds may have made their way into drinking water, they were not highly soluble, and the residues ingested in foods were of far greater concern. Synthetic organic pesticides were introduced during World War II and were thought to be far safer and more effective. These included chlorinated hydrocarbons such as DDT, aldrin, dieldrin, chlordane, heptachlor, lindane, endrin, and toxaphene. Because of their low solubility in water and their strong tendency to chemically attach to soil particles, these compounds have rarely contaminated groundwater. They originally were thought to be safe to humans and the environment, but later were discovered to accumulate in the environment and build up to toxic concentrations in food chains. Use of most of the chlorinated hydrocarbon pesticides, consequently, has been restricted, suspended, or canceled. One group replacing them has been the organophosphorous compounds such as malathion and diazinon. Although some organophosphorous compounds are highly toxic to humans,



they generally break down rapidly in the environment and rarely have been found in groundwater. Another group replacing the chlorinated hydrocarbons are carbamate pesticides including aldicarb, carbofuran, and oxamyl. These compounds tend to be soluble in water and weakly adsorbed to soil. Consequently, if not degraded in the upper soil layers, they have a tendency to migrate to groundwater. The most significant occurrences of groundwater contamination have been with the carbamate pesticides. Aldicarb has been detected in over 2,000 wells on Long Island as well as in 12 other states including Maine and New Jersey. As awareness has grown of the potential for pesticides to leach to groundwater, attention has focused on ways of changing registration and monitoring requirements to prevent such contamination from occurring in the future. Intensive studies have also been carried out in an attempt to determine what levels of pesticides are acceptable in water supplies.

### Health Effects of Pesticides

Studies of the health effects of pesticides on humans focus on two aspects, the acute toxicity, or immediate effects resulting from short-term exposure, and the chronic toxicity, or effects resulting from more-prolonged exposures. Acute toxicity typically is expressed as the concentration required to kill 50 percent of a population of test animals such as laboratory rats, either through

ingestion or through contact with the skin. These lethal concentrations can vary greatly from one pesticide to another. Aldicarb, for example, is considered to be highly toxic because the oral lethal dose is less than 1 milligram per kilogram (mg/kg) of body weight, compared with 500 mg/kg for carbaryl, or 5,000 mg/kg for methoxychlor.

When pesticides are found in water supplies, they normally are not present in high enough concentrations to cause acute health effects such as chemical burns, nausea, or convulsions. Instead, they typically occur in trace levels, and the concern is primarily for their potential for causing chronic health problems. To estimate chronic toxicity, laboratory animals are exposed to lower than lethal concentrations for extended periods of time. Measurements are made of the incidence of cancer, birth defects, genetic mutations, or other problems such as damage to the liver or central nervous system.

Although we may encounter many toxic substances in our daily lives, in low enough concentrations they do not impair our health. Caffeine, for example, is regularly consumed in coffee, tea, chocolate, and soft drinks. Although the amount of caffeine consumed in a normal diet does not cause illness, just 50 times this amount is sufficient to kill a human. Similarly, the oxalic acid found in rhubarb and spinach is harmless at low concentrations found in these foods, but will lead to kidney damage or death at higher doses.

#### Health effects of some pesticides found in groundwater

<i>Chemical name</i>	<i>Representative trade name</i>	<i>Chronic effects</i>	<i>Acute toxicity*</i>	<i>Acute effects at high concentrations</i>
alachlor	Lasso	Growth depression in laboratory animals	moderate	
aldicarb	Temik	None observed	high	Diarrhea, nausea, vomiting, abdominal pain, profuse sweating, salivation, and blurred vision
atrazine	Atranex	None observed	moderate	Mildly irritating to skin, eyes, and upper respiratory tract
carbofuran	Furadan	None observed	high	Diarrhea, nausea, vomiting, abdominal pain, profuse sweating, salivation, and blurred vision
chlorothalonil	Bravo	None observed in laboratory rats	low	
DCPA	Dacthal	None observed in dogs or rats	moderate	
1,2-dichloropropane	D-D	Possible liver and kidney damage	high	Acute gastrointestinal distress, with congestion and edema of lungs
ethylene dibromide (EDB)	Bromofume	Causes cancer, genetic mutations, and fetal deformities in some lab animals. Possible injury to lungs, liver, and kidneys from prolonged exposure	high	Headache, dizziness, nausea, drowsiness, tremors, seizures
oxamyl	Vydate	None observed	high	Diarrhea, nausea, vomiting, abdominal pain, profuse sweating, salivation, and blurred vision

Sources: SCAMP computerized data base maintained by Cornell University, and *Drinking Water and Health*, vol. 5, National Research Council, Washington, D.C., 1983.

\*Acute toxicity is defined to be the amount needed to kill 50 percent of a population of laboratory rats. It is expressed as milligrams of pesticide per kilogram of body weight. Ranges are defined as follows:

- high: < 500 mg/kg
- moderate: 500-5,000 mg/kg
- low: > 5,000 mg/kg



Laboratory measurements of a pesticide's toxicity must be interpreted in the context of its potential hazard under actual field conditions. Pesticides by definition are toxic to at least some forms of life, but whether or not a particular pesticide in groundwater is hazardous to human health depends on its concentration, how much is absorbed from water or other sources, the duration of exposure to the chemical, and how quickly the compound is metabolized and excreted from the body. Drinking water guidelines are aimed at keeping pesticides at levels below those that are considered to cause any health effects in humans. They are derived from laboratory data using one of two methods, depending on whether or not the compound causes cancer.

### Noncarcinogenic Compounds

For chemicals that do not cause cancer, a variety of tests are conducted on laboratory animals, bacteria, and tissue cultures to determine what daily dose produces no indications of toxicity. The lowest level from all these tests is defined to be the NOEL (no observed effect level) and is used as the starting point from which drinking water standards are derived. The NOEL for aldicarb is 7 mg/person/day, based on measurement of inhibition of an enzyme called cholinesterase in rats fed various doses for 6 months. Although aldicarb is the most acutely toxic pesticide registered by the Environmental Protection Agency, its hazard at levels typically found in groundwater is relatively low because it is rapidly metabolized and excreted. It does not accumulate in body tissues and has not been found to cause cancer, birth defects, genetic changes, or other chronic health problems in laboratory animals.

In setting drinking water guidelines, the acceptable daily intake (ADI) for a pesticide is calculated by dividing the NOEL by a "safety factor" determined by the level of uncertainty in the experimental data. If valid experimental results are available from studies on prolonged ingestion by humans, for example, a minimum safety factor of 10 might be chosen. This could increase to as much as several thousand if human data were lacking and laboratory data inconclusive. Most commonly, long-term animal feeding data are available, and a safety factor of 100 is used. This is based on the assumption that humans are roughly 10 times more sensitive to toxic substances than laboratory animals and that the susceptibility between different individuals can vary by another 10-fold. The resulting ADI represents an estimate of the amount of a pesticide that a typical person can consume daily for a lifetime with no adverse health effects. For aldicarb, the currently accepted NOEL is 0.1 mg/kg/day, and a safety factor of 100 is used, resulting in an ADI of 0.001 mg/kg/day.

The method for conversion from an ADI to a drinking water guideline varies from one agency to another. In New York State the 7 ppb guideline for aldicarb was derived in the following manner:

No Observed Effect Level (NOEL)	0.1 mg/kg/day =7 mg/70 kg person/day
Acceptable Daily Intake (ADI = NOEL/safety factor of 100)	7/100=0.07 mg/person/day
20% of daily intake in drinking water	0.07 × 0.2 = 0.014 mg/person/day
Average intake of 2 liters water per day	0.014/2 = 0.007 mg/liter
Drinking water guideline	0.007 mg/l = 7 ug/l or 7 ppb (parts per billion)

Although this appears to be a precise calculation, there actually is quite a bit of estimation and human judgment involved. Estimates must be made, for example, of the average weight of a person and the amount of water consumed per day. The percentage of the

daily intake of pesticide that would be consumed in drinking water must also be estimated, based on factors such as how much is contained in foods and whether the compound can also be absorbed through the skin while bathing. Although aldicarb has a high dermal toxicity, probably only negligible amounts would be absorbed through skin unless the pesticide is dissolved in oil or an organic solvent rather than water.

The U.S. Environmental Protection Agency calculated drinking water guidelines differently, basing the calculation on the amount that would be consumed by a 10-kilogram (22-pound) child who drinks 1 liter (approximately 1 quart) of water per day:

$$\begin{aligned} \text{Drinking water guideline} &= 0.001 \text{ mg/kg/day} \times \frac{10 \text{ kg child}}{1 \text{ liter/day}} \\ &= 0.01 \text{ mg/l, or } 10 \text{ ppb (parts per billion)} \end{aligned}$$

The resulting guideline is not intended to indicate a toxicity threshold, above which an imminent threat to human health exists. Instead, it is a health advisory that simply indicates a conservative estimate of the concentration that can be consumed in drinking water with no adverse health effects. Other sources of exposure, such as pesticides consumed in food, inhaled, or absorbed through the skin, are not included. The Environmental Protection Agency currently is attempting to revise this system to provide a more realistic assessment of total exposure from all sources.

### Carcinogenic Compounds

Drinking water standards are set in a different manner for carcinogenic pesticides. For compounds shown to cause cancer in laboratory animals, no NOEL or ADI is set. Current regulatory policy is that there is no specific threshold below which these chemicals do not cause an effect, although this is a matter of considerable scientific controversy. Instead of setting a threshold value, analysis focuses on the relationship between concentration and the risk of causing a specified number of cancer cases in a population of a specified size. Experiments with laboratory animals are used to correlate dose with expected frequency of cancer occurrence. These data are then extrapolated to humans, and regulatory decisions are made about the level of risk considered acceptable to human populations. Whether this level of risk is acceptable to an individual is a highly subjective and complex issue. Studies have shown, for example, that the public is willing to accept a risk as high as 1 in 10,000 from eating peanut butter, which may be contaminated with aflatoxin, a natural mold and one of the most potent carcinogens known to man, but would reject using a synthetic chemical with a cancer risk factor 100 times lower.

Federal regulatory agencies commonly define acceptable risk in drinking water to be one that causes no more than one additional case of cancer in a population of a million people who drink the water over the course of a lifetime. This risk is roughly the same as that of dying from diphtheria, polio, or German measles, or of being in a fatal plane accident. For pesticides that are carcinogenic, the concentrations causing no more than one cancer per million people typically are in the range of a few parts per trillion. In some cases these concentrations are so low that they exceed our capability for accurate laboratory measurement.

For most pesticides, drinking water standards have yet to be set. The Environmental Protection Agency has authority to develop nationwide standards, and some of the states are setting local standards as well. The New York State Department of Health has set advisory guidelines for aldicarb and carbofuran. Other organic pesticides are covered by a guideline limiting the concentration of any single organic chemical to no more than 50 parts per million and the combined concentration of all organics found to no higher than 100 parts per million. One of the complicating factors in setting



standards for the individual chemicals is that it generally is not known how a given compound might interact with other chemicals to affect human health. Often when one organic compound is found in groundwater, others are there also, and their effects together may be either greater or less than that observed when any one is ingested individually. The number of possible interactions makes thorough analysis of them all an impossible task. Health studies have been conducted of people drinking contaminated water supplies, but these studies are limited by the fact that many health problems are difficult to trace to a specific cause, especially since some cancers can remain latent for up to 40 years.

## Conclusions

Approximately 50,000 different pesticide products are used in this country, composed of over 600 active ingredients. Although the acute health effects of ingesting large amounts of a pesticide can readily be measured, the chronic effects of long-term exposure to low levels are much harder to define. Extensive laboratory experiments are required, and in many cases these experiments are incomplete or inconclusive. The Environmental Protection Agency is currently working on reevaluation of all pesticides registered before 1972 to bring them up to modern health standards and is requiring extensive testing of new products before they come on the market. Many questions remain, however, about the chronic health effects of pesticides and other synthetic organic contaminants in drinking water.

Establishment of drinking water standards is an inexact science, with many assumptions and value judgments needed in the conversion from laboratory animal data to an estimate of health effects in humans. The resulting standards represent the best judgment of regulatory authorities about the acceptable level of risk to people exposed to chemicals in drinking water.

Many pesticides and other synthetic organic compounds are potent chemicals with potential health effects in humans even at very low concentrations. The drinking water standard for aldicarb, for example, is 7 parts per billion, meaning that a single pound of this compound could contaminate the entire amount of water needed to supply the yearly needs of over 2,000 people. Clearly, it is of primary importance to keep such chemicals out of our water supplies. Following articles in this series will address issues important in preventing pesticide contamination of water supplies: protection of groundwater recharge, careful management of pesticides on the farm, government screening and regulation of pesticides, and use of farming methods that minimize damage to the environment.

**Acknowledgments:** Illustrations were drawn by Christine Cleveland and Donna Curtin, and Mary Jane Porter served as production assistant. Funding was provided by the New York Farmers' Fund. Many individuals reviewed the initial drafts, including Cornell University faculty members, northeastern Cooperative Extension agents, and employees of the U.S. Environmental Protection Agency and U.S. Geological Survey.

This publication is issued to further Cooperative Extension work mandated by acts of Congress of May 8 and June 30, 1914. It was produced with the cooperation of the U.S. Department of Agriculture, Cornell Cooperative Extension, New York State College of Agriculture and Life Sciences, New York State College of Human Ecology, and New York State College of Veterinary Medicine, at Cornell University. Cornell Cooperative Extension offers equal program and employment opportunities.

### Your Well: Evaluating the Potential for Pesticide Contamination

*Adapted from an article by Gary Jackson, University of Wisconsin*

You can evaluate the potential for pesticide contamination of your well using the following steps:

#### **Step 1. Evaluate the proximity of your well to areas of pesticide use.**

- Determine if wells in your area have been sampled and if pesticide contamination was detected.
- Determine location of areas where pesticides of concern have been used.
- Determine general direction of groundwater movement from these areas. (Groundwater flow generally follows surface contours, moving from higher areas toward lower discharge areas such as rivers, lakes, marshes, etc.)

The potential for pesticide contamination in your well probably is higher if pesticides have been detected in other nearby wells or if your well is located within 1 mile down-gradient from areas where pesticides are used on coarse, permeable soils.

#### **Step 2. Evaluate the construction of your well.**

- Check with your local health department about having your well and well casing inspected for sanitary construction.
- Determine the depth of the well into the water table. (This is approximately equal to the depth of standing water in the well.)

Shallow wells, such as those with less than 30 feet of casing or less than 10 feet of standing water in the well pipe, have a greater potential for contamination. However, even properly constructed deep wells may become contaminated under certain conditions.

#### **Step 3. Test for contamination.**

- Measure nitrate concentration. High nitrate levels often are found in wells with pesticide contamination, although low nitrate levels do not assure absence of pesticides. Your local health department or Cooperative Extension office can provide information on how to get your water tested.

## For Further Reading

- American Chemical Society. 1984. Chemical risk: A primer. Information Pamphlet available free of charge from American Chemical Society, 1155 Sixteenth Street, N.W., Washington, DC, 20036.
- Hayes, W.J., Jr. 1982. Pesticides studied in man. Williams and Wilkins, Baltimore, Md.
- Kim, N.K., and D.W. Stone. 1981. Organic chemicals and drinking water. New York State Department of Health, Albany.
- National Research Council. 1983. Drinking water and health. Vol National Academy Press, Washington, D.C.