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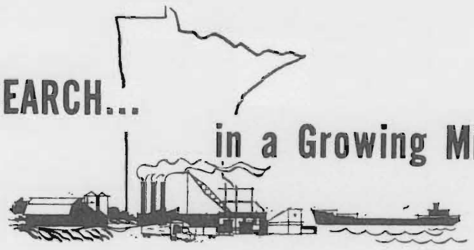
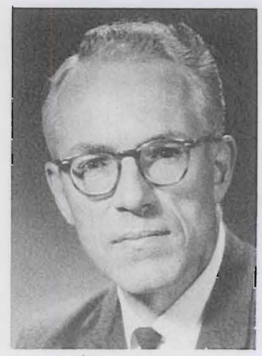
RESEARCH... in a Growing Minnesota





Dr. William F. Hueg, Jr.

During recent months environmental pollution, including water, land, and air pollution control, has been the focal point of widespread and intense public interest. More and more frequently we hear the phrase "maintenance of environmental quality" which seems more appropriate because it encompasses the enormous range of physical, biological, and economic problems confronting man and his world today.

Environmental quality control is not a new area of research to the University of Minnesota Agricultural Experiment Station. Its research program through the decades has focused attention on man and his environment. It has provided an opportunity for man to better understand the environment in which he lives and to develop methods whereby he could exact from this environment those things which we have come to regard as necessary to the "good life." Many of the projects established years ago in this area were not thought of as environmental quality control, but in fact results of this research have had that type of impact.

When we think of environmental quality in its largest context, it includes any endeavor that not only preserves resources but continually seeks to improve their natural state. In the agricultural sector this could mean eradicating disease and insect problems of livestock, poultry, and plants. Or it might mean developing new crop varieties or changing plant species so they are better adapted to the environment. Experiments in livestock breeding have taken into account the changing environment in which animals are raised and, in fact, attention must continue to be given to complete environment control for efficient livestock production.

Most problems that deal with environment are difficult to solve. A single disease, such as staphylococcal infection, has eluded scientific solution since its existence was established in 1870. Thousands of man-years have been concentrated in the effort to develop an effective vaccine against these infections. But the stubborn bacterial strain still persists today.

Cereal rust research programs have made it possible for man to understand and bring about some control of this disease. But in nature, rapid hybridization brings about new rust races that keep the plant breeder and plant pathologist busy developing resistant strains.

Studies of wildlife and fish habitats have been a major effort at the Minnesota Agricultural Experiment Station. Environment in spawning areas is critical if Minnesota's sports fishermen are to have an adequate supply. Knowledge and understanding of the habitat of such game bird species as the ruffed grouse have not only provided interesting academic information, but also have slowly resulted in an increase of this bird in areas of former abundance.

Each year the Experiment Station conducts field trials of crop varieties to evaluate and compare new hybrids and lines of plant material with established varieties. University crop scientists also conduct breeding experiments to develop uniformity in stands, early maturity, and disease-resistant progeny. At the same time, research on the rate and methods of applying agricultural chemicals is carried out to insure that these materials can benefit food production without harming our environment. It may not be apparent at first glance, but all these efforts contribute to man's economic well-being and quality of life.

Occasionally agricultural research may simply appear to be an attempt to exploit the productive efficiency of our land resource without regard for what effect fertilizers and pesticides have on the environment. But studies such as controlled tests to measure the amount of nutrient runoff from plots in which fertilizer has been plowed down, broadcast, or applied in bands, bear directly on the attempt to reduce pollution. Chemical control agents have also been carefully scrutinized and evaluated to determine their effect on crops, soil, and also livestock that feed on previously treated forages and grains. These tests have resulted in recommendations with respect to strength of mixtures, application rates, frequency of application, and a host of precautionary measures in handling agricultural chemicals.

Most research projects are conceived in terms of multiple objectives. Ten years of research on aortic rupture in turkeys has yielded valuable data on a similar condition in man. Studies of waste disposal not only hold implications for agricultural engineers, they also concern sanitation specialists, microbiologists, and soil fertility experts as well as pollution control engineers.

The complex relationship between agricultural research and environmental quality will be even more tightly interwoven in the years to come. Application of modern technology to traditional and new research projects should lead to faster identification and resolution of the problems that beset us. Computerized soil testing will enable farmers to determine precisely what nutrients their croplands lack. This will promote efficient use of fertilizer additives and reduce a potential source of pollution. Chromatographic analysis will aid scientists in their studies of pesticide residues. Infrared film will enable plant pathologists and foresters to pinpoint previously undetectable plant and tree diseases before they become fully established. Plant growth hormones will permit growers to time maturity dates when markets are most favorable.

Agricultural research, in the final analysis, goes far beyond maintaining the quality of our environment. It seeks to preserve what is valuable, and to overcome and master those destructive and harmful elements that are also part of our environment.

MINNESOTA SCIENCE

A publication of the University of Minnesota Agricultural Experiment Station

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Director — W. F. Hueg, Jr.

Editorial Committee — Craig F. Forman, chairman; Huai Chiang; Harold Dzuik; Joan Gordon; James Houck; Jean Lambert; A. J. Linck; and C. W. Young

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Craig Forman (inset photo) is the newly appointed editor of *Minnesota Science* and also serves as science writer-editor for the University of Minnesota Agricultural Experiment Station. He continues as a faculty member of the Department of Information and Agricultural Journalism where he was a publications editor for the past 2 years.

A native of Pipestone, Forman attended St. John's University and graduated from the University of Minnesota. He spent 2 years with the Military Advisory and Assistance Group in Bangkok, Thailand. Later he taught English and modern math in the Michigan school system. Then he returned to Pipestone to join the editorial staff of the *Farm and Market News, Nobles County Review,* and *The Pipestone Pioneer.* He came to the University from Pipestone.

Forman succeeds former editor Robert Turner, who made several improvements in the magazine's format during his 2 years at the post. Turner was involved in planning this issue.

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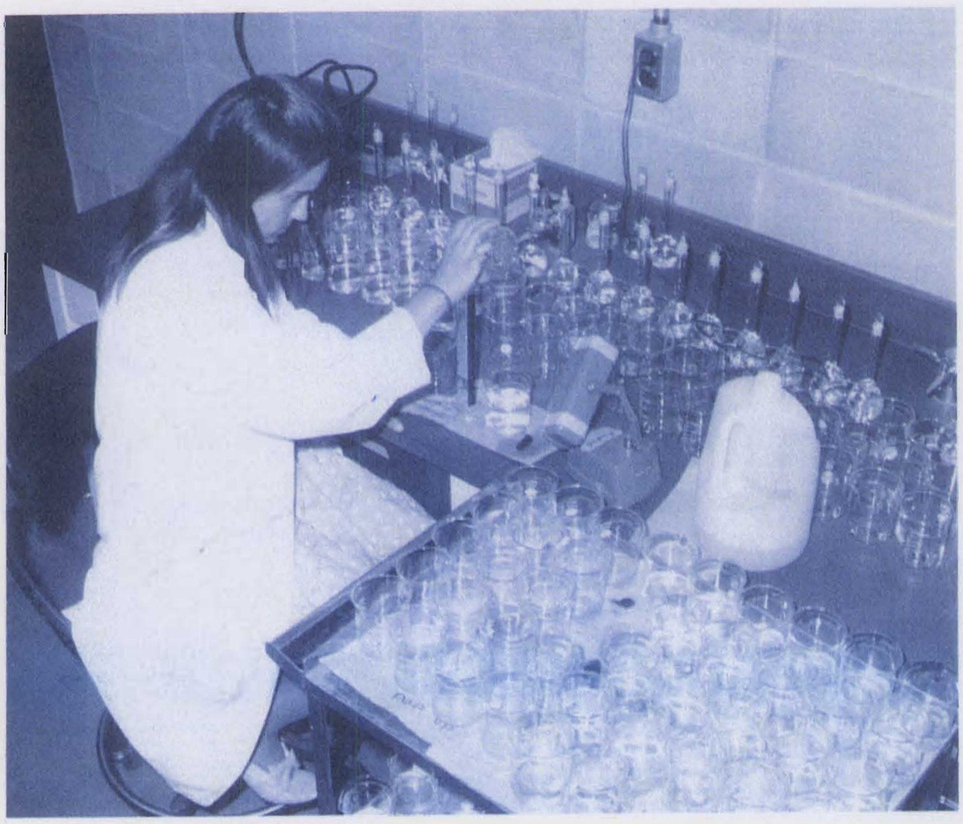
THE DDT SCARE
Do We Have All the Answers?

LAURENCE K. CUTKOMP
professor
Entomology, Fisheries and Wildlife



Lab technician Shelley Wooley assays the effect of pesticides on mosquito larvae after a 24-hour test period.

DDT has fallen into disrepute — despite its unmistakable and remarkable successes for over two decades. Reliable sources estimate that DDT has saved over 600 million lives from the ravages of mosquito-borne malaria, freed millions of acres of agricultural crops from insects, and rescued many, many square miles of paper and lumber-producing forests from multiple insect attacks.

DDT's most striking feature, its long-lived persistence, is a characteristic of great value for insect control. But this characteristic has also contributed to the downfall of DDT and its chemical relatives. Small, sublethal amounts of DDT and DDE, a less toxic breakdown product of DDT, have been found in fatty tissues of man, birds, fish, and smaller organisms, which form the food chain for birds and fish. Furthermore, DDT and dieldrin commonly persist for several years in treated soils and ground beneath orchard and shade trees sprayed to control pests.

CHANGING PATTERNS OF USE

Without question, domestic uses of DDT, DDD, aldrin, dieldrin, heptachlor, and endrin are rapidly declining. Many recommendations have been withdrawn for these chlorinated hydrocarbon pesticides, especially when a suitable substitute has been found. Organophosphate and carbamate compounds, such as malathion and carbaryl (Sevin), are replacing the questioned chlorinated hydrocarbons. These shorter-lived chemical replacements are detectable in crops, but they are less persistent.

Withdrawing the DDT group of compounds has resulted in a gradual decline of their presence in some living organisms and some soils. The degrading process for DDT compounds is slow but continuous and in time they disappear. This method of reducing DDT residues was first employed several years ago when dairy farmers were forbidden to feed DDT-contaminated hay to milking cows or directly spray barns and animals with DDT compounds. Consequently, levels of DDT, DDE, and DDD in marketed milk were reduced to quantities not to exceed 50 parts of the insecticide per billion parts of milk. This minute quantity is roughly equal to 1 ounce of contaminant in 20 railroad tank cars each holding 150,000 gallons of milk. A regulated type of control has been an effective tool for growers, including dairymen. U.S. dairy farmers and food growers will lose their livelihood if they fail to abide by label requirements administered by the federal and state agricultural departments, or if products exceed legal tolerances established by the Federal Food and Drug Administration (FDA) to protect consumers.

INSECTICIDE PERSISTENCE AND HUMANS

Persistent insecticides have caused concern in two major areas: their effect on human beings and on wildlife. Human tissues and organs have been analyzed for insecticides since 1950. Fatty tissues are the chief repository for DDT, DDE, dieldrin, and similar compounds. No measurable ill effects occur in fatty tissues, but the deposits indicate the degree of insecticide burden.

Over 1,000 samples have been analyzed since sensitive gas chromatographic techniques became available. In the United States (1962-1966) the average person had 2.6 parts of pure DDT per million parts of fat, and 7 ppm of the less toxic breakdown product, DDE. Comparative analyses show higher levels (13.5 ppm of DDT) among India's population. Countries such as Israel and Poland also have higher levels on the average than those in the U.S. Somewhat lower values were recorded among Canadians and populations of several western European countries. The compound dieldrin, used less extensively than DDT, averaged 0.14 ppm in the U.S., about 1/20 of the amount of DDT found.

The chief source of insecticide traces is food, notably meat, fish, and poultry (about 40 percent), followed by dairy products, fruits, cereals, and vegetables. A 1965-67 survey revealed that 28 and 21 *micrograms* of DDT and DDE were present in a large daily intake of food (meals large enough to satisfy the appetite of a 16 to 19 year old boy). On a comparative basis, 28 micrograms is approximately one-millionth of one ounce.

To provide up-to-date information on detectable residues the FDA conducts "Market Basket" surveys six times each year in five geographic regions of the United States (including Minneapolis). Experiments have verified a predictable relationship between food intake and DDT storage in fat. The detectable amounts of DDT and related compounds found in fat have not changed significantly during the last 15 years, except for a small decline reported in 1966.

Several medical studies have assessed the effects of low levels of chlorinated hydrocarbons on man. In one study, volunteers were fed doses of DDT 200 times greater than levels found in an average diet. Medical examinations revealed no abnormalities in any of the volunteers. This experiment was completed nearly 15 years ago.

More recently chemical workers who had been exposed to DDT for periods ranging from 11 to 19 years were given thorough medical examinations. Their body fat showed levels of DDT that were from 39 to 128 times greater than that found in the general U.S. population. Findings from medical histories, physical exams, clinical tests, and chest x-rays revealed no ill effects from their exposure to DDT.

These studies represent only a portion of the experimental evidence. The health of people has been studied in several regions where pesticides are heavily used. A few of the areas studied were the orchard areas of the Pacific Northwest; citrus-growing areas of California, Arizona, and Texas; the cotton growing lands of the south; and intensively cultivated croplands of Florida. The United Kingdom has also made similar studies.

The overwhelming conclusion is that there is no evidence to support the charge that residues of pesticides are endangering man. Even chronic DDT poisoning has not been detected in humans, including many spraymen and formulators of persistent insecticides.

INSECTICIDE RESIDUES AND WILDLIFE

Insecticide residues in wildlife bring up several points that have also generated concern. Persistent insecticides display the same characteristics in all wildlife species, and the organisms on which they feed, as pesticides do in man. This means that insecticides of this type are long-lived, accumulate in fatty tissues, degrade slowly, and are detected in greatest quantities in fats. DDT, and sometimes DDE, is associated with soil particles, and these sometimes get blown into the atmosphere. Also very minute amounts are found in some bodies of water.

Because this review must be brief, little attention is given to early incidents where the unwise use of insecticides killed certain fish and wildlife. Situations where spraymen used a large dose of a persistent insecticide (because it was the most efficient way) with little concern for the game birds in the area are also passed over. These unfortunate happenings took place in early days of use. No such large scale treatments occurred in the Upper Midwest. Almost from the outset, it has been known that most fish and crustaceans (shrimp, crayfish, crabs, and lobsters) were very sensitive to most chlorinated hydrocarbons. Some early users failed to take this into account.

The greatest concern centers on how traces of these insecticides affect all living things, particularly those highly regarded by man. DDT has been found in many animals. Levels approach the same range found in humans.

In one study several animals collected from a Long Island estuary contained DDT. Amounts ranged from 40 parts per billion in tiny organisms called plankton to 75.5 parts per million in ring-billed gulls. The largest amounts of residues in this and other studies, were found in carnivors and scavengers. These animals normally eat more contaminated organisms containing DDT and DDE in their fatty tissues. However, in an uncontrolled situation many diverse organisms are involved where the precise source and amount of the persistent insecticide may be unknown.

Laboratory data provide a more reliable means to interpret the meaning of this information. Substantial experimental evidence shows that animals exposed to DDT, DDD, and dieldrin show neurological symptoms (tremors are evident), but this occurs with rather high doses. Those animals are affected only after insecticides have reached a critical level in the brain and nervous tissues. Carefully controlled experiments with rats showed that exposure to more than 200 parts per million of DDT in the brain was required before tremors appeared. Amounts deposited in fatty tissues of the rats could not be related to symptoms.

More subtle effects related to low-level DDT and DDE residues have been reported. Hatching problems of carnivorous bird eggs is one of the most frequently occurring difficulties. A recent 618-page book devoted to the decline of the Peregrine falcon populations shows that chlorinated hydrocarbon residues are correlated with thinner egg shells.

Similar problems have been noted among bald and golden eagles, ospreys, and the Bermuda Petrel, an ocean-going bird of the Atlantic. Much of this evidence appears to be circumstantial. One carefully controlled experiment showed that DDT had no harmful effect on sperm from treated male bald eagles. The most pertinent findings involve indirect evidence showing a deficiency in available calcium. This has been related to the production of thinner egg shells and a "calcium hunger" of birds exposed to DDT and dieldrin. The crux of the disagreement primarily rests on whether the amount of insecticide encountered is sufficient to produce the effect.

Researchers have had difficulty showing adverse effects in any animal when minute quantities of pure DDT were used. As a result, attention has been directed to two compounds closely associated with DDT. One is an isomer, or errant DDT molecule, called ortho-para prime DDT, which constitutes about 20 percent of commercially produced DDT. USDA researchers are working to determine its effect on reproduction in the Japanese quail, a sensitive laboratory bird. Others are wondering if DDE, the metabolite of DDT, can upset metabolism and jeopardize reproductive success. This has not been resolved.

AN ANALYTICAL PROBLEM

Proper identification of DDT residues further complicates the already snarled question of how hazardous minute residues are to bird and fish. Certain industrial chemicals used as plasticizers and for other purposes can appear in the same analytical region as DDT (using gas chromatography) and might be mistaken for DDT. Conceivably those chemicals could be the culprits that are plaguing bird eggs. Clearly, some DDT analyses are suspect. The issue is far from being closed.

WHAT CAN WE CONCLUDE?

Domestic uses of DDT and related compounds are rapidly falling off. As a result, detectable amounts of the chlorinated insecticides are slowly declining. They are still present, however, and pesticide monitoring stations are operating all over the United States. They ensure not only human protection, but also monitor residue levels in wildlife, food, and water. There is no indication of hazard to humans from the minute residues. However, subtle effects, particularly those affecting reproduction in birds, are associated with low residue values.

Further research will be needed to resolve the validity of these reports, and also to provide analyses that discriminate between minute amounts of DDT and unsuspected chemicals.

Economic Aspects of Water Quality

JOHN J. WAELTI
assistant professor
Department of Agricultural Economics

ROBERT C. LEWIS
research assistant
Department of Agricultural Economics

Unabated pollution of Minnesota's lakes and streams is becoming an increasingly important factor in the quality of our state's physical environment. Burgeoning industrial development, greater population concentration in urban centers and around lakeshores, and inadequate waste treatment in many communities are adding to the amount of wastes entering Minnesota waters. Use of waterways for waste discharge is competing with recreational uses and undercutting the aesthetic quality of our environment.

Pollutants of two major categories, degradable and nondegradable, cause deterioration of Minnesota's water resources. Degradable pollutants include organic matter discharged by municipal, industrial, and other sources. The organic material is decomposed by biochemical processes after it enters into waterways. These materials are broken down by bacteria in a process that uses oxygen, which is dissolved in the water. Gradually, the organic matter undergoes decomposition and in the process the stream becomes purified. However, the capacity of each waterway to purify organic matter is limited. The amount of flow, the surface area, turbulence, and temperature of the water all play a hand in the process. If the waste load is too heavy for the stream's capacity to purify, the amount of oxygen dissolved in the water becomes dangerously low. As a result, game fish and other desirable aquatic life perish.

In contrast, nondegradable pollutants are not altered by biochemical processes once they enter waterways. These pollutants include some chemical compounds and nutrients such as nitrates and phosphates. Farm lands, and fertilized lawns and golf courses are sources of nutrients, which wash off after rainfall or snowmelt. Nutrients also remain from the breakdown of degradable materials. Nutrient pollution stimulates excessive algal and aquatic weed growth in lakes and slowly flowing streams. The same nutrients that promote vigorous plant growth on land also foster underwater plant growth.

Many other forms of pollution trouble our lakes and streams, but organic matter in streams and nutrient pollution in lakes are the most widespread and problematic. Both forms of pollution, oxygen-demanding wastes and nutrients, have common economic aspects.

LOSS OF ECONOMIC PRODUCT

Lakes and streams are valuable assets to society. They furnish water for municipal and industrial use, for recreation, and a host of other uses. Pollution severely reduces the value of water, especially for recreational and aesthetic uses. This reduced value is a direct loss to society, though it is difficult to measure these losses in dollars and cents. A lake clogged with algae is certainly not as valuable for recreation as a clear lake.

Uncontrolled water pollution could hold severe economic consequences for Minnesota because a large part of our tourist trade is attracted by the state's high quality lakes and streams. If lakes deteriorate to the extent that game fish are replaced by rough fish, or to the extent that swimming, boating, and waterskiing are no longer enjoyable, tourist trade would be drastically curtailed.

If nobody favors pollution, and it clearly represents an economic loss to society, why is it allowed to continue? A major reason is that while pollution is costly, pollution control also involves costs. Additionally, costs of pollution and costs of controlling pollution do not fall to the same people.

If pollution control laws don't exist or if they are not enforced, municipalities and industrial firms use the cheapest means to dispose of wastes. The cheapest means for industry is to take advantage of the purifying capacity of streams to decompose wastes. Similarly, there is pressure for municipalities to keep taxes low by not providing adequate waste treatment facilities.

Since the costs of pollution in terms of deteriorating lakes and streams is shifted from municipal and industrial pollutors to society, the pollutors see little reason to incur pollution control costs.

A similar example exists in instances of nutrient pollution of lakes. Consider the case where several resorts and several hundred homes around a lake discharge varying amounts of nutrient-laden wastes into the lakes. The contribution of each pollutor is small in relation to the total. However, if a single individual bore the expense of providing adequate waste treatment facilities, the costs to the individual would far outweigh the benefits he received if others continued to pollute the lake. The all-too-familiar result is that the problem is ignored until pollution reaches crisis proportions.

The only effective means of controlling pollution is for every potential pollutor to have access to adequate waste treatment facilities. Effective control further requires cooperative community action as well as a strong sense of social responsibility among individual citizens.

POLICY DECISIONS

Although economic decisions have an important bearing on water quality, these decisions are meaningful only in the context of the total problem. A useful way of organizing the policy issues, of which economic aspects are a part, is as follows:

1. What are the best means of attaining a given level of water quality?

Although several technical solutions exist to improve water quality, some are more economically or politically feasible than others. There is probably less controversy on this set of issues than in the remaining two.

2. What level of water quality should be attained?

Alternatives range from no waste treatment to complete waste treatment designed to maintain waters close to their natural state. Few would urge no waste treatment. Most citizens would likely opt for cleaner water than we now have in Minnesota. The central question is "What resources will be made available for pollution control in Minnesota and how strictly will polluters be regulated?" Private resources and tax revenues are limited. Resources for pollution control must compete with countless private and public wants and needs.

3. What is the best means of implementing a water quality control policy?

Even the most idealistic plans for water quality control are worthless if they cannot be put into effect. An effective water quality control policy normally involves an agency that is responsible for monitoring and enforcing standards. Such an agency depends on the willingness of citizens and legislators to provide the necessary technical and legal staff. In turn the staff requires sufficient monitoring equipment and legal authority to enforce regulations.

The decisive factors regarding Minnesota's water quality in the future, as in the past, will be political. Increasing concern among citizens over Minnesota's water quality problems has provided the momentum necessary to bring about political action necessary for higher water quality standards and more stringent enforcement.

SULFUR FALLOUT
Does It Injure Plants?

EDWIN C. SEIM
research assistant
Department of Soil Science

ALFRED C. CALDWELL
professor
Department of Soil Science

For centuries man has considered the earth's atmosphere a limitless commodity. Cliches such as "free as the air" reflect this carefree attitude toward the earth's air supply. But, in fact, it is not present in endless abundance. The great mass of air that envelopes the earth varies from 6 miles in depth at either pole to 10 miles at the equator. But the small portion which sustains life, sometimes called the "breathosphere," extends only a few thousand feet above sea level. Even this "breathosphere" is not always entirely available due to unfavorable climatic conditions.

Man has polluted the atmosphere for thousands of years, but in the last half-century the rate of pollution has accelerated alarmingly. During this same time, man's need for unpolluted air has grown increasingly greater.

Major pollutants of the earth's atmosphere are sulfur dioxide, carbon monoxide, carbon dioxide, ozone, fluoride, sulfuric acid droplets, smoke dust, toxic metals, and hydrocarbons.

Sulfur dioxide is perhaps the best known gaseous air pollutant. Since it is present in the atmosphere nearly everywhere, it is often a general index of air pollution. Power plants, busses and trucks, home heating plants, and factories all contribute sulfur dioxide to our atmosphere. The gaseous pollutant is colorless, noninflammable, heavier than air, and it mixes easily with water.

In low concentrations it affects breathing and at higher concentrations it irritates the eyes, nose, and throat. High sulfur dioxide concentrations were conclusively linked to the major air pollution disasters, which resulted in hundreds of deaths in London, New York City, and St. Louis.

Sulfur dioxide exerts both a toxic and beneficial effect upon plant life, depending on its level of concentration. Damage to vegetation may be acute or chronic. Acute damage results from distinct fumigation; chronic damage to plants may be caused by prolonged exposure to low concentrations of sulfur dioxide gas. But at very low concentrations the gas may have no harmful effect on vegetation if it is converted to sulfate. In this state, it may be used by plants to form sulfur-containing compounds such as protein and certain enzymes. Different plant species and varieties vary considerably in their susceptibility to sulfur dioxide damage.

Sulfur content in rainfall was investigated as early as 1825. Rainfall was found to contain sulfate particles, which occur naturally in sea spray or may be formed through a chemical reaction that produces sulfur trioxides. This gas then reacts with water vapor to form hydrosulfuric acid.

Early investigations of sulfur dioxide in the atmosphere made use of a lead-dioxide-coated fabric on a

Photo by Midland Cooperatives

Sulfur-laden smoke drifts away from a Lake Superior dredge.

spool, called a "lead dioxide candle." This method has been updated by more sophisticated sampling techniques, but the lead dioxide candle still provides the best means of measuring sulfur dioxide concentration over long time intervals.

Work is now underway to determine what role soil plays in removing sulfur from the atmosphere through natural processes. The cyclical nature of atmospheric sulfur is well known but almost no measurements have been made during various stages of the cycle.

In Minnesota, investigations of the sulfur dioxide content of air and rainfall, along with other research on sulfur nutrition of plants, were carried out during the 1930's by Dr. F. J. Alway and his Experiment Station coworkers.

More recent research efforts were initiated in 1962 with studies of sulfur fertilizers and sulfur nutrition of legumes, corn, and small grain, and sulfur fallout. The amounts of sulfur contained in the atmosphere and deposited by rain and snow were measured at four sites in Minnesota: two rural areas — Lamberton and Park Rapids — and two urban sites — Duluth and St. Paul. Atmospheric sulfur was measured by exposing the lead dioxide candles to the atmosphere for one month and then replacing them with fresh candles. Exposed candles were analyzed using the method described by Alway and his associates.

Rainfall and snow were collected in Alway-developed gauges, and amounts were recorded immediately after each snow or rainfall ended. Snow and ice were melted and measured in liquid state. All precipitation was stored and grouped into monthly samples over a 5 year period beginning January 1963.

For the entire period sulfur in the atmosphere ranged from a low of 5.8 pounds of sulfur per acre at Park Rapids to a high of 36.4 pounds per acre at St. Paul. "Candles" exposed at Lamberton registered nearly the same amount as Park Rapids (6.2 pounds). But at Duluth they absorbed nearly twice as much sulfur, 10.1 pounds, as at Park Rapids.

Most monthly averages maintained the same spread over the 5 year period. But sulfur levels in the industrial St. Paul area rose during the winter months to 14 times the Park Rapids levels. During summer months, it again fell to within three times the Park Rapids' values.

Sulfur content in precipitation collected at Park Rapids averaged 3.65 pounds per acre each year compared to 14.71 pounds at St. Paul. Yearly averages at Duluth and Lamberton were almost identical, 8.01 and 8.29 pounds per acre.

The amount of sulfur directly absorbed by the soil varies considerably. But Alway found that it usually averaged about 22 percent of the amount absorbed by the lead dioxide candles. This figure was used to calculate how much sulfur was directly absorbed by the soil at each site. That amount was then added to the total sulfur deposits contributed by precipitation. Final annual estimates of the amount of sulfur added to the soil at each location from atmospheric sources averaged 4.93 pounds at Park Rapids, 9.6 pounds at Lamberton, 10.2 pounds at Duluth, and 22.7 pounds per acre at St. Paul.

Distribution of sulfur deposits at each of the four sites falls into distinct patterns. At Park Rapids and Lamberton the pattern is one of nearly uniform absorption throughout the year. During summer months absorption levels rise slightly or peak. Summer peaks at these two sites probably come from natural sources of atmospheric sulfur. Winter peaks, such as those that occur in St. Paul, however, indicate increased fuel consumption during the heating season. These peaks can almost undeniably be attributed to industrial and urban air pollution.

The amounts of sulfur deposited by precipitation show no seasonal fluctuation. No significant connection between the amount of precipitation and the amount of sulfur deposited is evident. After a long dry period, a large amount of sulfur may fall with a small amount of precipitation. Similarly, after the atmosphere has been "cleansed" of accumulated sulfate, a prolonged rainfall may bring down only small amounts of sulfur.

The amount of sulfur being brought to the soil by rain and snow has declined in the metropolitan area. In 1936 Alway reported that 25.96 pounds of sulfur were deposited by precipitation at the University farm and that figure climbed to 27.9 pounds the following year. When amounts declined to nearly half that figure in 1963, researchers decided to investigate possible explanations for this change as part of their overall study of sulfur nutrition. The principal reason appears to be that types of fuels being used in homes and by industry dump much less sulfur dioxide gas into the atmosphere. The switch from coal, which contains two to four percent sulfur, to fuel oils (maximum of 2.5 percent) and natural gas with no sulfur content, drastically cut back the amount of sulfur in the atmosphere. The drop in sulfur content might have been even greater if it had not been offset by tremendous industrial and urban growth, and increased numbers of automobiles and trucks. For every 1,000 gallons of gasoline burned, an estimated 17 pounds of sulfur dioxide gas is released into the atmosphere along with countless other byproducts that pollute the air.

The amount of sulfur in precipitation at Park Rapids appears also to have declined but it has been slight. No previous figures are available for comparison with levels at Duluth and Lamberton.

Results of the 5-year study indicate that the atmosphere of the Twin Cities metropolitan area contains considerable amounts of sulfur. Whether these levels are high enough to damage plant life is difficult to determine without further study and improvements in data-gathering equipment. Midwinter pollution levels are certainly capable of injuring plants, but injury would be confined to coniferous and other evergreen vegetation capable of absorbing large quantities of gases.

Many north central Minnesota soils are naturally low in sulfur, and on sandy soils some sulfur may be lost by leaching. For this reason, along with low atmospheric sulfur levels, many crops grown in that area are sulfur deficient. This is especially true for crops like alfalfa, which contain high amounts of protein and sulfur.

Soils in the metropolitan area will not require sulfur fertilization as long as the current level of pollution continues. However, more information on the effect that sulfur from atmospheric sources has on the acidity of these soils and their subsequent nutrient-supplying capacity is needed.

LEAD POISONING
Man's Ancient Foe

P. B. HAMMOND
professor, Veterinary Physiology
and Pharmacology

In recent years the controversy centering around pesticides has obscured the fact that lead poisoning continues to plague wildlife managers, livestock owners, veterinarians, and public health officials. Industrial lead poisoning, which once affected large numbers of workers, has nearly been brought under control. But other exposures affecting children, livestock, and wildlife have not been substantially reduced.

Lead poisoning was first recorded centuries ago among ancient Greek miners and smelters. Lead was a popular item of commerce then because it could be easily procured and refined. Since lead withstood corrosion far better than most other metals available, it was used to construct primitive plumbing systems and also for kitchen vessels in wealthier homes. Poorer Greeks and Romans used earthenware for cooking and drinking.

The fall of the Roman Empire, according to one theory, may have resulted from the effects of chronic lead poisoning on the ruling classes. Sterility and madness among adults, and mental retardation among children of the upper class patricians were common. Studies of lead concentrations in the bones of wealthy Romans support the theory. This type of exposure to lead was apparently not considered dangerous since it was common practice to sweeten wine with lead acetate. This practice was eventually recognized as extremely hazardous centuries later. Some medieval officials even imposed the death penalty for adulteration of beverages with lead.

This mallard exhibits the classic symptoms of lead poisoning — drooped head and wings.

Photo courtesy of Jerry Longcore, Patuxent Wildlife Research Center, U.S. Dept. of Interior.

By the late 19th and early 20th century many new uses for lead were introduced, including lead pellets for shot guns, lead paint pigments for homes and artwork, and a host of other uses.

During this period of technological advance, poisoning among workers in lead-using industries reached shocking proportions. Most legislation enacted then to protect workers from industrial lead poisoning can be traced to aroused public opinion over the issue. Today, industrial lead poisoning occurs far less frequently and in a much milder form.

Perhaps the most tragic aspect of lead poisoning is its effect on infants. At one time, virtually all paint contained high concentrations of lead, making any painted object a potential source of lead poisoning. This was unfortunate for children who developed the habit of licking and chewing inedible objects or who craved unnatural foods.

The craving for unusual foods, often referred to as *pica,* is also common in livestock, particularly when their diet is deficient in certain minerals. Curiously, lead poisoning in infants wasn't extensively recognized until after World War II, although it undoubtedly existed before then.

Lead poisoning in infants is hardly noticeable at first. The child experiences stomach pains and is irritable. This may go on for some weeks before the child is taken to a doctor. The rather common symptoms of lead poisoning were overlooked by physicians many years ago and simply regarded as an upset stomach.

However, the ensuing nervous disorders that often follow the onset of lead poisoning are extremely serious and often fatal. If the child survives, his brain may be permanently damaged or, at best, impaired for several years.

Today, lead-bearing paints and other finishing materials are no longer used indoors or on objects to which infants have ready access. Yet poisoning continues to occur, mostly in slum areas where dwellings abound with crumbling plaster and flaking paint, and where children are poorly supervised.

Lead poisoning in livestock was recognized as a serious problem in a bygone era when horses served as the principal source of power. Lead poisoning was a common affliction of animals that worked in lead smelters or lead product factories. Horses, however, reacted differently than humans to lead poisoning. After prolonged exposure, nerves controlling the chest and throat muscles became paralyzed. Poisoned horses exhibited a peculiar rattling in the throat, commonly referred to as "roaring," when they were exercised. The advent of the gasoline engine marked the decline of the horse, and lead poisoning in horses became a rarity.

Today, the domestic animal most frequently affected is cattle. In fact, lead poisoning is one of the most common toxicological problems of livestock in this area, due almost solely to Minnesota's large cattle population. Cattle, along with young children, share the unfortunate habit of chewing and eating foreign objects, including painted boards. Cattle have actually drunk fresh paint that was carelessly left lying around.

Greases are also attractive. A dozen or so cows on a farm near Princeton, Minnesota cleaned out a tub of gear compound containing lead. Nearly half the animals died. Old car and tractor batteries are also a popular item with cows. The acid taste is probably attractive because it adds zip to an otherwise bland diet.

Lead-poisoned cattle often die so suddenly that owners suspect lightning stroke. But a correct diagnosis can be made because lead is detectable in tissues of dead animals. A search of the premises usually turns up the source of the trouble. Animals that survive long enough to receive professional attention often recover.

Lead poisoning in cattle also affects the nervous system. Odd behavior patterns may take the form of severe depression (sometimes referred to as "dumb form") or exaggerated movements or even convulsions. Unlike children, cattle that recover rarely show any lingering brain damage.

Other domestic animals are poisoned much less frequently than cattle. Several factors contribute to lower incidence among other animals. Most animals are less inclined to eat or drink inedible material. Also, absorption of lead from the stomach and intestine is not as great. The large paunch of cattle acts as a trap for dense material like gravel, nails, wire, and probably for some forms of ingested lead such as paint flakes. The longer a substance remains in the stomach and intestines, the more completely it is absorbed.

In recent years debates on the effect of pesticides on wildlife have overshadowed the fact that lead poisoning is also taking its toll, particularly among waterfowl.

The problem is hardly new. Instances of lead poisoning in ducks and geese were described by German researchers as early as 1842. Sporadic episodes in this country were reported at the turn of the century and continue today.

All birds require grit as grinding material in their gizzards, which acts as a substitute for teeth. They swallow and retain small pebbles or coarse sand for this purpose. The bottoms of lakes and streams that are favorite hunting haunts are heavily sprinkled with lead shot. Birds seeking underwater roots and seeds frequently pick up the lead shot. The shot remains in their gizzards as if it were pebbles. The grinding action and strong acid secretions of the gizzard then erode the shot and convert it to lead salts which are absorbed by the bird.

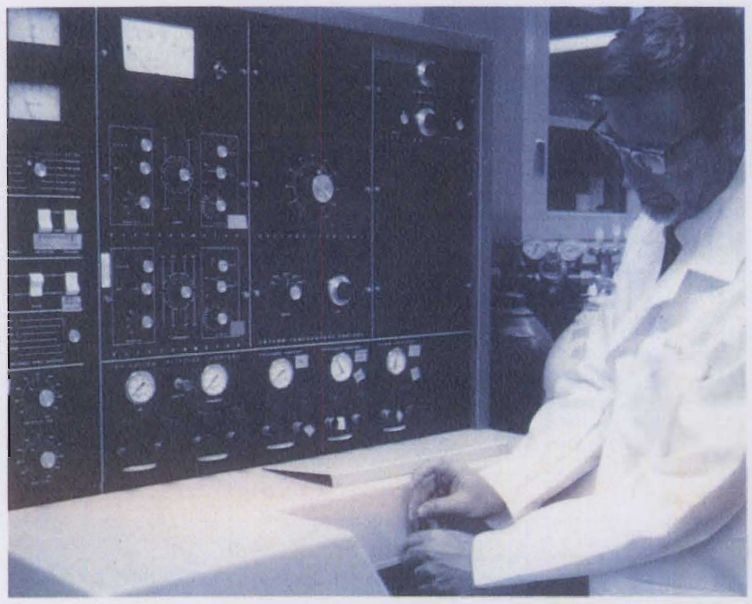
Sometimes spectacular "die-offs" involving hundreds and even thousands of birds occur when flocks feed in lead-infested waters. Countless individual birds are also poisoned and die unnoticed in remote places. Conservationists estimate that four percent of the mallard ducks traveling the Mississippi Flyway die each year from lead poisoning. Annually, between two and three percent of all wild waterfowl in this country are fatally poisoned. The problem will probably get more serious as the number of wildlife feeding areas steadily declines.

Efforts have been underway for several years to develop nontoxic shot. Some approaches include coating the shot with plastic, substituting other metals for lead, and mixing magnesium with lead so that spent shot will dissolve quicker. Iron shot is the most promising substitute, but it would be more costly to produce. Hunters might be willing to pay more for ammunition once they become convinced that the bird population is being seriously jeopardized by lead shot. Most conservationists feel that lead shot can be outlawed only through public pressure. And they think that the time to force the issue is now, before it is too late.

Misconceptions About Pesticide Residues in Soil

RUSSELL S. ADAMS, JR.
associate professor
Department of Soil Science

Throughout the world people concerned about pesticides residues are playing a numbers game: ten parts per million here, three parts per billion there, one part per trillion somewhere else. How many of you can visualize one part per trillion? It's like sorting through 1,280,000 bushels of wheat for one kernel of smutty grain. A staggering task, yet it is easily accomplished with modern techniques when looking for pesticide residues. But even scientists who are familiar with methods used to measure pesticides often find it difficult to interpret how important these small amounts are. No wonder that those unfamiliar with amounts as small as one part per trillion have trouble understanding their importance.



Author R. S. Adams, Jr. injects a pesticide sample to be analyzed into the gas chromatograph in his laboratory.

Current confusion and misconceptions regarding pesticide residues may be directly connected with development of more sophisticated analytical instruments. These devices make extremely sensitive *quantitative* measurements, but exceed our ability to interpret the measurements. Without supporting data one can only assume that the compound measured is the sought-for pesticides. Often the only way to establish the identity of these minute amounts is by circumstantial evidence.

Absolute proof of the identity of residues requires expensive and involved purification and concentration in the laboratory. When DDT is present in a sample at less than the prescribed level of tolerance, investigators rarely go to the trouble and expense of confirming its identity. Failure to use adequate purification techniques has undoubtedly led to many false claims of the presence of DDT.

There are many naturally occurring compounds, and some synthetic organic compounds being added to our environment that "look like pesticides" when they pass through analytical instruments. For example, several root crops contain compounds which cannot be separated from aldrin and dieldrin (see charts A, B, and C) on some gas chromatographs — the device used to analyze samples. This fact has been known for years. Yet some pesticide analysts still appear unaware of it.

Cyanuric acid and similar compounds are also common in soil organic matter. These natural compounds can interfere with some determinations for the triazine herbicides since these herbicides are made from cyanuric acid.

A large number of previously unidentified chlorine-containing compounds have been detected in bird and fish samples. Recently these compounds have been identified as polychlorinated biphenyls; compounds that are used in petroleum products, rubber, coolants and several other products. They are reported toxic to wildlife and affect their calcium metabolism. (Holmes, D. C., *et al.* Nature 216: 227-229. 1967.) Since these compounds are used extensively, since they resist chemical breakdown, and are easily confused with DDT, some early findings that pointed to widespread DDT contamination are open to question.

Table 1. Amount of DDT required to kill one-half the flies in a bioassay over a 24-hour period in three different soil types*

	ppm
Zimmerman sand	92
Nicollet clay loam	159
Blue Earth clay loam	428

* Data courtesy of James Peterson, Soil Science Department, University of Minnesota.

Table 2. Effect of ¾ parts per million of simazine on the growth of oats*

	Without simazine	With simazine
Zimmerman sand	0.41	0.13
Nicollet clay loam	0.48	0.27
Blue Earth clay loam	0.44	0.67

* All figures represent gram weight of the dry stems grown in pots containing different soil types.

Neither the amount of these compounds present in our soil and water nor their potential effect on our wildlife has been studied.

Another misconception fostered in recent years centers around the idea that the accumulation of any amount of pesticide residues in soils constitutes a potential hazard. Pesticides do persist longer in soils. For example, about one half the DDT sprayed on an apple tree disappears in 7 days. If that same DDT falls on soil, it may take 7 years for one half the DDT to disappear. However, the amount of pesticides accumulated in soil offers no direct indication of the biological effect that a pesticide is likely to have.

One reason why DDT persists in soil for such a long time is that it is *adsorbed* by soil. Adsorption may in no way change the DDT. While adsorbed to soil particles, however, it is less potent and cannot control insects as effectively. Furthermore, its resistance to breakdown by microorganisms is increased. For this reason it remains much longer in soil than on the surface of plant tissue.

The effect of soil adsorption on the biological activity of DDT and simazine is shown in tables 1 and 2. Adsorption of either DDT or simazine by the soil reduces its activity. The potential toxicity of any pesticide residue varies with the type of soil containing the residue. With both these chemicals, organic matter in the soil plays the greatest role in the adsorption process. Small amounts of *s*-triazine herbicides have been known to stimulate plant growth. This effect was observed with simazine in Blue Earth clay loam where ¾ parts per million actually increased the growth of oats. But oats planted in Zimmerman sand were killed (see table 2). Clearly, the amount of pesticide present in soil is not a measure of its potential hazard. Hazard resulting from exposure to or consumption of a pesticide must be a combination of many factors including the effective dose, chronic and acute effects, and the amount and frequency of exposure.

Contrary to popular belief the persistence of a pesticide in our environment does not necessarily indicate a greater human hazard. Potential danger to human health, may, in fact, be greater from the use of less persistent pesticides. Dr. D. D. Kaufman has observed that with herbicides of aromatic chemical structure (the 2,4-D's) any change in chemical structure that increased soil persistence decreased its toxicity. ("Pesticides and their Effects on Soils and Water," American Society of Agronomy Special Publication No. 8, 1966. pp. 85-94.) This concept may be roughly applied to all pesticides. Some of the less persistent pesticides in soil are quite toxic. Larger amounts of less persistent chemicals must be used to ensure that enough pesticide is present for control when the invasion occurs. If the timing of application is not right then a second application may be necessary. In either case, more chemical must be used and the chance of accidental exposure to toxic amounts looms larger.

The term "toxicity" is often carelessly used. Pesticides are selective chemicals: They are highly effective against some pests and much less deadly to other animals. For instance, a lethal dose of DDT to a mass of house flies weighing 1 pound is approximately 0.01 gram. About 2.5 grams are required for a 15 pound rabbit. But that dosage would hardly faze a 9 pound chicken. A dose of 6 grams, more than double the amount lethal to the larger animal, would have to be administered.

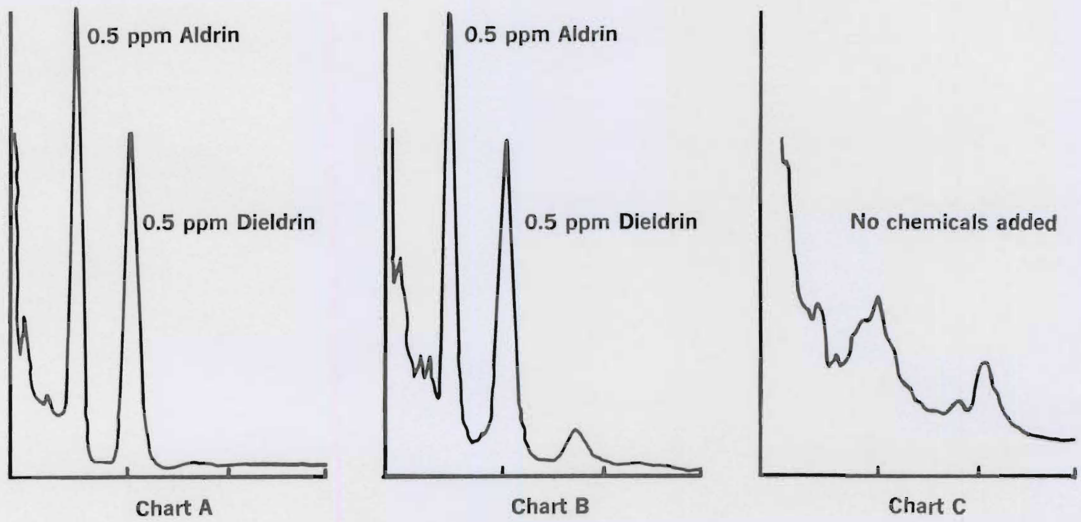
Many microscopic bacteria survive in almost pure pesticide environments. Not only are these bacteria unaffected by the pesticide, they use it as a source of food. It is apparent, then, that "toxicity" has little meaning unless it is expressed in terms of dosage (i.e., a given quantity of pesticide per pound of live weight of a specific organism).

The reputed worldwide distribution of DDT also raises some questions of credibility. Pesticides are normally used over limited areas. For them to be distributed all over the globe requires some means of transport either by atmospheric or water routes. Much of the pesticide used eventually reaches the soil, either by direct application or by rainfall which washes it from plant surfaces. A great deal of the pesticide reaching the soil may be degraded by microorganisms in the soil or through chemical reaction with soil water. Pesticides move out of the soil either by vaporization, through leaching, or by surface runoff — all potential sources of environmental pollution.

Factors that determine whether a pesticide will vaporize from the soil depend on how strongly the chemical is adsorbed by soil particles and how soluble it is in water. Since the hard pesticides are weakly adsorbed by soil colloids and because they do not easily dissolve in water and are not easily broken down by chemical or other means, the major avenue of escape from soil is vaporization. Because this is a slow process it has never been considered a serious source of pollution. Moreover, most pesticides exist only a short time in the atmosphere due to the degrading effects of ultraviolet rays in sunlight.

If DDT is truly present in the Antarctic snowcap, the only way it could have arrived there is through the atmosphere. Neither the mechanisms of atmospheric distribution nor the stability of pesticides in the atmosphere have been studied well enough outside the laboratory to make any firm conclusions, however.

Leaching, as well, is not generally regarded as a major source of pesticidal pollution. Most pesticides that are soluble enough to leach are easily broken down. Note in table 3 that the more water soluble, less persistent atra-



The three charts shown above illustrate how naturally occurring chemical compounds in root crops might be confused with residual levels recorded for aldrin and dieldrin by a gas chromatograph. Chart A is a recording of the two pesticides alone. Chart B shows the two chemicals mixed with carrot extract. Chart C is a recording of the natural residues present in a carrot extract that was not treated with chemicals. Note that the peaks or high points on Chart C resemble those recorded for aldrin and dieldrin in both Charts A and B. This phenomenon can elevate recorded levels of undesirable residues in food above their actual values. Data courtesy of Jon Barber, Soil Science Department, University of Minnesota.

zine moved down through the soil profile. But the persistent (organochlorine) insecticides remained near the surface where they were applied.

Pesticides usually are carried from where they were applied to another point in a field or to streams by soil movement. The incidence of pesticides in streams or lakes results either from direct and intentional application, from promiscuous discharge or disposal of chemicals and containers, or through runoff of sediments from treated fields. Most documented fish kills have resulted from disposal of pesticide wastes or containers directly into streams or at locations that drain into nearby streams.

The number of fish killed by pesticide-bearing sediments is unknown. Due to low water solubility of pesticides the amount of pesticide detaching from a sediment particle is about one molecule for each 1,000 adsorbed. (Warnick, S.L., *et. al.* Journal of American Waterworks Association 58:601-608. 1966.) Normally this would not release enough pesticide to present a hazard to fish. However, the problem is more complex than this ratio suggests. Bottom-feeding fish, such as carp, continually churn the sediments. When rough fish are present, game fish are forced to exist in turbid waters. Direct transfer of pesticide from sediment to fish seems likely. This possible mode of transfer has been largely neglected. Furthermore, biological concentration via the food chain must not be ignored.

Table 3. Recovery of pesticides from 4 inch columns of Fayette silt loam soil after leaching with deionized water*

Depth	Atrazine†	Aldrin	DDT	Endrin
Inches	Percent of the pesticide recovered			
0.4	1.39	98.26	98.65	94.40
0.4-0.8	1.48	0.72	1.01	1.14
0.8-1.2	1.29	0.19	0.06	1.10
1.2-1.8	1.39	0.10	0.07	2.10
1.8-4.0	1.11	0.72	0.20	1.25
Total found in leachate	93.34	Trace‡	Trace	Trace

* Data courtesy of Dr. George Madany and Mrs. Janice Ley, formerly of the Soil Science Department.

† Atrazine column was leached with 40 inches of water and the insecticide columns with 28 inches.

‡ Only dieldrin was recovered in the leachate; aldrin was apparently converted to dieldrin in passing through the soil.

The use of the so-called "hard" pesticides by farmers has rapidly declined during the last decade. In many rural regions of the United States agricultural use of DDT is practically nil. Instead, the principal use of DDT is mosquito and Dutch Elm disease control in rural towns and cities. A study by the Federal Water Pollution Control Administration in 1966 indicated that in the Cincinnati, Ohio area the principal source of organochlorine pesticide residues in streams was urban. (Weibel, S. R., *et al.* Journal of American Waterworks Association 58: 1075-1084. 1966.)

As our technology advances; as our population expands; and as our people become more affluent, greater burdens will inevitably be placed upon our natural environment. The task of contending with our wastes will become increasingly greater. The amount of pesticidal pollution contributed by rural sources will undoubtedly change as our technology advances. As of now the total amount contributed by the rural community is relatively static and, if anything, it is likely to decline. In future years, the real battle against environmental pollution will be waged in our cities and metropolitan areas rather than the sparsely populated countryside.

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Poisons, Pests, And World Food Problems

PHILLIP K. HAREIN
professor and extension entomologist
Department of Entomology, Fisheries and Wildlife

In America where overeating has become a problem, it is difficult to understand that 65 percent of the world's population suffers from malnutrition. We also are unmindful that at least 50 percent of the people on this earth are desperately in want of virtually everything that we regard as bare necessities of life. This means that hundreds of millions of humans today live not only without adequate food, but also without adequate clothing, shelter, water, and even simple sanitation to protect them from disease and harmful insects. Their average life span scarcely reaches beyond 30 years.

Expanding world food production generates a demand for more effective pest control, and in turn encourages a rapidly growing pesticide industry. In the United States, farmers, industrial and governmental users, and home owners are becoming increasingly aware of the usefulness of chemicals to control pests. Total U.S. production of pesticides in 1967 amounted to about 1 billion pounds — with a manufacturing value of $800 million.

The U.S. Department of Agriculture estimates that without pesticides, we would lose more than 30 percent of our protein supply and more than 80 percent of our high vitamin crops. Our food supply would dwindle under attacks from some 6,500 harmful species of insects and rodents and the effects of 50,000 known plant diseases. Food prices would double.

Today, the average American family spends about 16 percent of its daily living expenses on food. This figure is considerably higher in other countries. Canadians spend 22 percent, Australians 23 percent, and Danes 24 percent. Swedes, Belgians, Puerto Ricans, Britains, and Norwegians spend slightly less than 30 percent on food. In the 30 to 39 percent group are South Africans, French, Irish, Finns, Spaniards, and Panamanians. The rest of the world pays out 40 to 70 percent of its daily living expense on food.

This difference in food cost is not solely the result of pesticides. But pesticides form a vital link in the chain of events involved in food production.

Prohibiting pesticide use in the United States would greatly alter our eating habits and lower our standard of living. The relatively low cost of food in the U.S. has released 90 percent of our people from the farm, permitting them to spend 80 percent of their effort on production other than food. This enormous human resource has staffed our schools, colleges, and research laboratories. It has built our cities, bridges, and highways; worked our mines and industries; created our cultured arts; and made our nation a leader in today's world and in space.

As with automobiles, drugs, and firearms, man must weigh the advantages and disadvantages of continued use of pesticides. We must make the right decisions if we are to grow. To make the correct decision, we must fully comprehend the problem. Chemicals used for pest control are correctly called poisons. Their misuse has resulted in unnecessary losses of property, wildlife, and humans. To reduce these losses, it is absolutely necessary that pesticides be used properly.

We must conclude that chemicals, including pesticides, are an essential part of food and fiber production and marketing. It is obvious that in years to come these chemical tools will be used even more extensively.

Similarly, there is no reason to believe that the use of pesticides to control medically important insects will decrease. In the foreseeable future we will probably rely heavily on chemicals to cope with critical pest problems. Also we will undoubtedly develop better pesticides that are safer and more effective against resistant pests.

The value of all possible pest control methods to society is enormous. We not only need them, we are highly dependent on them, especially to meet growing world demand for increased food and fiber production.

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