OCCURRENCE AND SIGNIFICANCE OF DDT AND DIELDRIN RESIDUES IN WISCONSIN FISH

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By

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Finances for the 1966 and 1967 surveys were made available by Chapter 36, 1965 Supplement to the Wisconsin Statutes (36.245), known as "The Accelerated Water Resources Research and Data Collection Program." This support provided funds for salaries of project personnel and for equipment required in analyzing the fish samples.

Implementing the three-year survey required the coordinated efforts of many Department of Natural Resources personnel. Collections of living fish were made by field personnel stationed in many locations of the state. Linda C. Hall and James Weckmueller assisted in the data analysis. Donald R. Thompson prepared the interim report covering the 1965 survey and provided technical assistance in planning and reporting this investigation.

Edited by Ruth L. Hine

COVER PHOTO

Helicopter treating elm trees with DDT in the spring to kill beetles that carry Dutch elm disease. (Photo by *Milwaukee Journal*)

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INTRODUCTION

The chlorinated hydrocarbon pesticides usually reach our waters in concentrations that are not fatal to fish. Unfortunately, these substances tend to accumulate in the environment and may persist in the toxic form for years, becoming absorbed in plants and animals and adsorbed on soils. When present in sufficient concentrations, toxic residues of chlorinated hydrocarbon pesticides have been shown to change behavior, interfere with reproduction, and kill a variety of animal life. This group of pesticides constituted approximately 52 percent of all insecticides and 30 percent of all pesticides produced in the United States in 1965 as indicated by the U. S. Department of Agriculture's Pesticide Review (1966). It is officially estimated that in the United States, agricultural chemicals which include the chlorinated hydrocarbon pesticides were responsible for 32 percent of all known sources of fish kills in 1960, 21 percent in 1961, and 18 percent in 1962 (Tarzwell, 1965).

Evidence of significant residues of the chlorinated hydrocarbon insecticides DDT and dieldrin in certain Wisconsin fishes prompted the Department of Natural Resources to conduct a survey to determine the amounts of these residues in a variety of fishes from many state waters. The survey findings were prepared by Thompson (1966) and Kleinert et al. (1967). The present report presents all of the information obtained to date together with a discussion of the significance of these data. A perspective section is included to acquaint the reader with the use, movement and accumulation in the environment, concentration in fish, and general toxicity of DDT and dieldrin. This perspective section is not intended to completely review the subjects introduced, but is developed to orient the reader to the nature of the pesticides studied.

It was not possible to include every geographical area of Wisconsin in the sampling program. However, we believe a sufficient number of waters and species were included in the study to establish a general picture of pesticide residues of DDT and dieldrin in Wisconsin fish. This survey effort represents the largest collection of fish taken for chlorinated hydrocarbon pesticide analysis in Wisconsin to date.

The survey program included 561 whole fish samples—122 in 1965, 365 in 1966, and 74 in 1967. These samples represent more than 2,670 fish of 35 species from 109 inland lakes and streams of Wisconsin, the Mississippi River, and Wisconsin's coastal waters of Lakes Michigan and Superior analyzed for DDT and dieldrin in the survey program. In terms of coverage 510 samples were taken from 42 Wisconsin counties containing 830,412 acres of surface water or almost 75 percent of Wisconsin's inland surface water, 35 samples from the Mississippi River, 6 samples from Lake Michigan, and 10 samples from Lake Superior.

Wisconsin fish samples have also been collected and analyzed for chlorinated hydrocarbon pesticides by University of Wisconsin researchers interested in problems in specific localities, the Wisconsin Department of Agriculture which monitors residues in agricultural products, including fish sold for human consumption, and the Department of Interior's Bureau of Commercial Fisheries which is monitoring pesticide levels in fishes of the Great Lakes, including Wisconsin's coastal waters. In the present study the Department of Natural Resources took few samples from Lakes Michigan and Superior because such sampling would have duplicated the monitoring activities of the Bureau of Commercial Fisheries.

MATERIALS AND METHODS

The selection of waters and fishes to be sampled was determined by a committee representing the Research, Fish Management, Game Management, Forest Management, and Engineering Bureaus of the Department of Natural Resources. A cross-section of Wisconsin lakes and streams, as well as a number of waters located near urbanized, agricultural, or pest control areas thought to be high pesticide use areas were selected for sampling. The fishes chosen for sampling chiefly consisted of the common game, pan, and rough fish species of wide distribution in state waters.

Collections

Collections of living fish were made chiefly between the months of May and October of 1965, 1966, and 1967. These collections conformed as closely as possible with instructions supplied to field personnel specifying species, size, and number of fish to be collected. In most cases, samples consisted of 3 to 10 fish of the same species or if larger fish were available, each was handled as a single sample.

Sample Preparation

All fish samples were prepared for analysis at the Department's Nevin Laboratory. Samples were wrapped tightly in aluminum foil, frozen shortly after capture, and held in the freezer. The frozen fish constituting each sample were ground whole in a meat grinder, mixed, and reground three times; aliquots of each sample were selected and

Trap netting fish for pesticide analysis at Lake LaBelle in Waukesha County. (Photo by C. O. Harris, Waukesha)

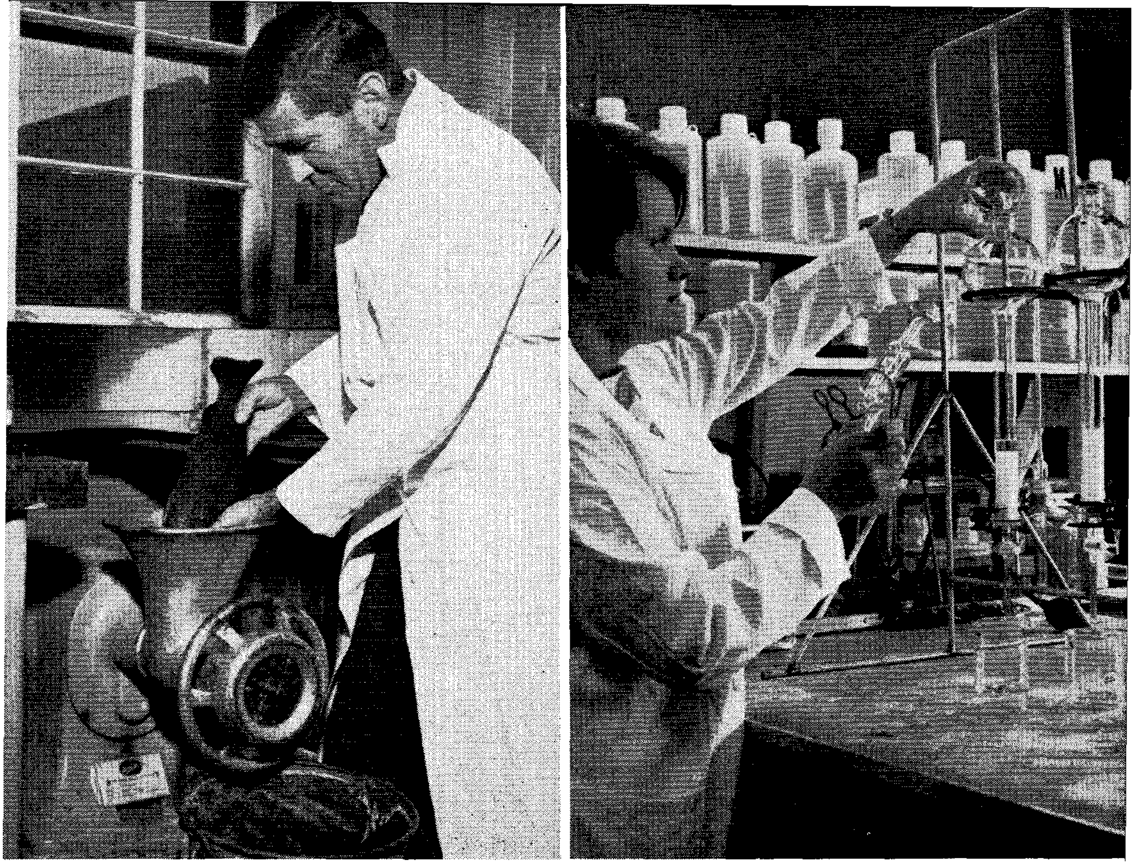
Adult walleye taken for pesticide analysis. (Photo by C. O. Harris, Waukesha)

stored in capped sample bottles at $-11°$ C. until analysis. Throughout preparation, the fish samples were kept in a frozen, or near frozen condition.

Moisture determinations were made by drying ground whole fish samples for 8 to 12 hours in a forced-air oven at 102° C. Fat determinations were made on the dried samples by continuous extraction with ethyl ether for 8 to 10 hours.

Pesticide Analysis

All of the whole fish samples collected in this study were analyzed for the chlorinated hydrocarbon pesticides DDT and dieldrin. Pesticide analysis for most samples collected in 1965 was done by the Wisconsin Alumni Research Foundation Laboratories in Madison. The remainder of the samples collected in 1965 were analyzed at the Wisconsin Department of Agriculture Pesticide Laboratory in Madison. Both laboratories employed gas chromatography using analytical



procedures described for animal tissues by the U. S. Department of Health, Education and Welfare (1965). Both laboratories analyzed fish fat samples and reported DDT, DDE, DDD, and dieldrin as parts per million in the fat ("fat basis").

All fish samples collected in 1966 and 1967 were analyzed for DDT and dieldrin by the Department of Natural Resources Nevin Laboratory using pesticide analysis procedures described for animal tissues by the U. S. Department of Health, Education, and Welfare (1965), except that acetronitrile partitioning was omitted. Thus, the concentrated extracts were placed directly on deactivated florisil columns and eluted with 6 percent ethyl ether and 94 percent redistilled hexane. The deactivated florisil columns passed both DDT and dieldrin on the first elution. The cleanup procedure was completed by passing 1 ml. of extracted sample through a sweep codistillation apparatus consisting of glass tubes packed with glass wool. This sample was then ready for injection into the gas chromatograph.

DDT and dieldrin residue levels were determined by electron capture gas chromatograph (Beckman Model GC-5), utilizing a mixed bed column, 2 mm. i. d. by 6 feet glass, packed with 9 parts

(Left) Grinding whole fish in preparation for pesticide analysis at the Nevin Laboratory.

(Middle) Technician passes concentrated extracts of fish samples through deactivated florisil columns in preparation for DDT and dieldrin analysis.

(Right) Chemist reads gas chromatograph peaks for DDT and dieldrin residues in fish samples.

10 percent DC200 and 5 parts 10 percent QFL on Gas Chrom Q, 60–80 mesh. The column temperature was 210° C., and the flow rate was 26 ml. helium per minute. The detector temperature was 250° C., the injector temperature 220° C. The Nevin Laboratory reported residues of DDT, DDD, DDE, and dieldrin as parts per million of the whole fish ("whole fish basis").

For comparative purposes the data from the Wisconsin Alumni Research Foundation and Wisconsin Department of Agriculture laboratories were converted from the "fat basis" to the "whole fish basis", while the Department of Natural Resource's data were converted from the "whole fish basis" to the "fat basis". These conversions rest upon the assumptions that all DDT and dieldrin residues are extracted with the fat and that random 10-gram samples of ground and mixed whole fish have a fat percentage similar to the fat percentage of the whole fish. These assumptions may not be entirely valid; therefore all residue data reported here as well as the residue data conversions are to be regarded as estimates. We believe these estimates reflect the true magnitude of pesticide residues of the fish samples analyzed as closely as present-day technology allows.

PERSPECTIVE

Use of DDT and Dieldrin in the United States

The great toxicity of DDT to a wide range of insects, as well as its persistence, fostered the belief that it was the answer to nearly all insect problems. Dieldrin came into use after DDT had been widely used and accepted. Since the introduction of DDT in 1943, many pest species have developed resistance to it as has been the case with dieldrin. Newer pesticides have replaced DDT and dieldrin for certain uses, but the chlorinated hydrocarbons are still the most extensively used insecticides in the U. S.

It has been estimated that 89.5 million acres in the 48 contiguous states receive insecticides in an average year. This land includes 0.3 percent of the forest land, 28.3 percent of urban and built-up land, 15 percent of agricultural land, and 0.5 percent of other land. Of the insecticide poundage used in the U. S., 0.8 percent is used on forest land, 24.8 percent on urban and built-up land, 73.2 percent on agricultural land, and 1.2 percent on all other land (Tarrant, 1966).

Use of DDT and Dieldrin in Wisconsin

Comprehensive records of the amounts of pesticides used in Wisconsin do not exist. Neither are figures available on the amounts of pesticides sold in Wisconsin. Therefore, quantitative statements about pesticide use in the state are difficult to make. Some general information on uses of DDT and dieldrin can be summarized, however, and is presented below under the categories, agricultural, forest and noncrop, industrial, and household uses.

Agricultural. Wisconsin is a significant user of pesticides for agriculture but does not use the quantity of pesticides as do certain other important agricultural states, such as California. California alone uses almost 20 percent of all pesticides used in the United States (Bailey and Hannum, 1967). The total agricultural insect pest control program in Wisconsin covers about 400,000 acres (Apple, 1967), compared with a total land area of 21,000,000 acres in farms in 1967 (Walters et al., 1967).

University of Wisconsin, College of Agriculture, recommendations have been tending away from DDT, aldrin (which degrades to dieldrin) and dieldrin for agricultural insect pests because of failure of control in some instances, due to development of resistance by the pest and because of crop contamination in other instances. In the case of cranberries, DDT usage was discontinued voluntarily by

◀ **Under the protection of breathing mask, sun glasses, heavy gloves and a waterproof coat and hood to ward off the chemical mist, a Port Washington city employe sprays elms with DDT. (Photo by Vern Arendt, Port Washington)** growers after the 1966 season because of concern over possible contamination of rivers and lakes (Apple, 1967).

DDT (or DDD) is still recommended for control of one or more pests on the following crops: potatoes, tomatoes, beans, carrots, lettuce, celery, cucumber, squash, onions, spinach, horseradish, asparagus, beets, apples (Apple, 1967), tobacco (Wis. Agricultural Extension Service, 1968a), and strawberries (Wis. Agricultural Extension Service, 1968b).

Dieldrin and/or aldrin are recommended for certain pests on onions, potatoes, beans, tomatoes, carrots, corn (Apple, 1967) and strawberries (Wis. Agricultural Extension Service, 1968b).

Vegetable crops, many of which are dusted or sprayed for insect and disease control in Wisconsin, are concentrated in the following counties: Columbia, Fond du Lac, Portage, Dane, Dodge, Outagamie, Rock, Manitowoc, St. Croix, Sheboygan, Langlade, Sauk, and Waushara (U. S. Bureau of the Census, 1964).

Apple acreage, which amounts to 10,000 acres (Apple, 1967) is intensively treated with pesticides; 6 to 8 treatments per year are sometimes given these areas. In Door County, an area of about 400 square miles containing most of the state's 10,000-acre cherry orchard industry, it is estimated that 30 tons of DDT and 15 tons of DDD were used annually (Hickey et al., 1965). These chemicals were discontinued in the 1966 recommendations of the Wisconsin College of Agriculture (Apple, 1967) for cherries.

A recent study of an orchard in Door County disclosed that during one 3-year period (1963–65), approximately 100 pounds actual dieldrin were applied each year in foliar treatment of the entire orchard (195 acres). From 1955 to 1962, approximately 50 pounds actual dieldrin had been applied annually. DDT and other pesticides had also been used in this orchard, but total amounts were unknown (Moubry et al., 1968).

Forest and Non-crop Lands. Use of DDT for control of Dutch elm disease still continues in spite of encouragement given to the use of methoxychlor. Because of the widespread use of DDT, the location of most urban areas on waterways, and the rapidity of run-off from paved urban areas on waterways, Dutch elm disease spraying is considered to be an important contributor to the DDT load of certain Wisconsin waters.

The following information is contained in the 1967 Dutch Elm Disease Report prepared by the Wisconsin Department of Agriculture. Dutch elm disease is found in 50 of Wisconsin's 72 counties. This disease is of special economic importance due to the large number and high proportion of elm trees in many Wisconsin communities.

Crop dusting plane treating corn in Washington County during the summer of 1968. (Photo by Don Johnson, *Milwaukee Sentinel*)

Prior to 1962 elms numbered 9,500 in Fox Point, 17,029 in Janesville, 12,225 in Kenosha, 11,127 in Shorewood, 7,792 in Watertown, 40,000 in Wauwatosa, and 32,000 in West Allis. In these communities elms constituted from 40 to 99 percent of the trees.

The Wisconsin Department of Agriculture's 1968 recommendations for Dutch elm disease control include spray applications of DDT or methoxychlor during the dormant period, but caution against indiscriminant use of these pesticides or their use in areas where serious contamination of aquatic environments could occur. Application rates of DDT for a single Wisconsin city give an indication of the amounts of DDT used in treatment programs. In 1966, Janesville sprayed 6,300 elms by helicopter with a 16.6 percent DDT solution. Approximately ½ pound of DDT was used per tree. In the same year, Janesville treated 6,800 elms by rotomist sprayer with a 12.5 percent DDT solution. Approximately one pound of DDT was used per tree.

Use of DDT has been discontinued on all lands owned and controlled by the Department of Natural Resources since 1965. As the Department is responsible for insect control on forest lands, this is an indication of the importance attached to the problem.

The Wisconsin College of Agriculture advises against the use of persistent insecticides for mosquito control, recommending instead fogging with malathion, naled or pyrethrins (Wis. Agricultural Extension Service, undated publication). In spite of this, DDT is probably still in use against mosquitoes in the state.

Industrial. Among the formulators of pesticides such as DDT and dieldrin are pest control firms and tree-spraying operators in addition to chemical companies. The manufacture and formulation of these chemicals requires registration with the Wisconsin Department of Agriculture. Pesticide-formulating businesses, as well as cooperage firms that reclaim used pesticide-containing drums, should be considered as possible sources of pesticide contamination of waters.

Firms which use chlorinated hydrocarbon pesticides in manufacturing include concerns which use DDT or dieldrin for mothproofing woolens. These chemicals may be applied during manufacture or dry-cleaning. A 1962 survey of 50 commercial dry-cleaners, chosen at random, showed that DDT is routinely applied to all clothing, including cottons, synthetics and woolens, by 30 percent of the dry cleaners questioned. Usually the cleaner is unaware of the identity of the active chemical agent in the mothproofing compound (Coulson, 1962). Dieldrin may also be used by cleaners for mothproofing.

Household. DDT and dieldrin are recommended by the Wisconsin College of Agriculture for control of several household pests. DDT is recommended for ants, cockroaches, millipedes and centipedes, pantry pests, and silverfish (Wis. Agricultural Extension Service, 1968a).

The U. S. Department of Agriculture recommends DDT and dieldrin for nearly all lawn insect pests and suggests aldrin for grubs and ants, sod webworms, wireworms, cicada-killer wasp, and wild bees (U. S. Department of Agriculture, 1966).

DDT is recommended by the U. S. Department of Agriculture for use against insects on the following vegetables in the home garden: asparagus, beans, beets and chard, carrots, celery, onions, peppers, potatoes, squash and pumpkin, sweet corn, tomatoes, turnips, and mustard. DDT is also recommended onblackberries and dewberries. Dieldrin appears in recommendations for sweet potatoes and seed treatment with dieldrin is recommended for beans (U. S. Department of Agriculture, 1967).

DDT and Dieldrin Contamination of the Environment

Movement in the Environment. DDT is now found practically everywhere, while dieldrin commonly occurs in many areas of the natural environment. Both have been detected in surface water, ground water, soil, air, food, clothing, crustaceans, fish, other animals, and humans not only in the United States but in many areas of the world.

Sources of pesticide pollution of water include run-off from the land, direct discharges of industrial waste, or direct application as a consequence of treatments for pest control. Aerially applied pesticides may also be carried by air currents, circulated through the lower troposphere, and later deposited by rainfall in distant places (Woodwell, 1967).

Accumulation in the Environment. Water: It is evident that the pollution of waters by pesticides is widespread. In spite of the very low solubility of the chlorinated hydrocarbon pesticides in water, dieldrin, DDT, and its analog DDE have been found in water samples from all major river basins of the United States (Weaver et al. 1965). Studies of two California rivers revealed definite seasonal trends in the pesticide content of the streams which were associated with agricultural practices in the two river basins (Bailey and Hannum, 1967).

Soils: Pesticide concentrations in soils and sediments are much higher than those in water. The chemical half-life of stable chlorinated hydrocarbons in soils, and the time they remain active against some soil insects, are measured in years (President's Science Advisory Committee, 1963a). Chlorinated hydrocarbon pesticides are adsorbed by soil particles and retained by organic material in the soil. In a muck soil of high organic content, insecticidal residues are bound to the soil particles to such an extent that the same amount of toxicant is less effective in a muck soil than in a sandy one (Lichtenstein and Schulz, 1959). Bailey and Hannum (1967) found the highest pesticide concentrations were generally found in sediments with smaller grain sizes in California streams, and the lowest pesticide concentrations were associated with larger grain sizes and inorganic materials such as fine to coarse sand. Other important factors associated with the fate of chlorinated hydrocarbon pesticides in soils include soil organisms and soil temperatures. Johnson et al. (1967) demonstrated the conversion of DDT to DDD by pathogenic and saprophytic bacteria associated with plants under anaerobic conditions. Hill and McCarty (1967) demonstrated that many chlorinated hydrocarbon pesticides were degraded under suitable biologically active anaerobic conditions. These investigations showed DDT converted rapidly to DDD under anaerobic conditions, but persisted as DDT under aerobic conditions; evidence indicated dieldrin was persistent under both aerobic and anaerobic environments. Soil temperatures influence both the loss through volatilization as well as the breakdown of the insecticide by biological and chemical factors (Lichtenstein and Schulz, 1959). Soils and sediments act as storage areas for pesticides. Ferguson et al. (1965) found endrin and DDT in bottom muds near cotton fields in amounts sufficient to kill fish when these pesticides were removed with acetone extracts; these muds containing adsorbed pesticides failed to release lethal quantities of toxicants into standing water.

Plants and animals: Studies of plants of agricultural importance have shown that pesticides are absorbed from soils into plants. Many crops have been investigated after growing in insecticide-treated soils. It has been found that "root crops", especially, contain residues of insecticides, the amount depending on the crop, the soil type, and various other conditions (Lichtenstein and Schulz, 1960 and 1965; Lichtenstein et al. 1965).

Scientific literature abounds with data documenting the world-wide occurrence of chlorinated hydrocarbon residues in animal life. Residues occur in all components of the ecosystem. The President's Science Advisory Committee (1963a) described the distribution and persistence in the environment of chlorinated hydrocarbon pesticides as follows: "DDT residues have been detected at great distances from the place of application and its concentration in certain living organisms has been observed. DDT has been found in oil of fish that live far at sea and in fish caught off the coasts of eastern and western North America, South America, Europe, and Asia. . . . Residues of DDT and certain other chlorinated hydrocarbons have been detected in most of our major rivers, in ground water, in fish from our fresh waters, in migratory birds, in wild mammals, and in shellfish. Small amounts of DDT have been detected in food from many parts of the world including processed dairy products from the United States, Europe, and South America. . . . In the United States, DDT and its metabolites have been found in the fat of persons without occupational exposure at an average of 12 ppm for the past 10 years. . . . The distribution and persistence of other chlorinated hydrocarbons have been studied in less detail, although some of these chemicals have been widely applied. One of these, dieldrin, resembles DDT in stability, persistence, and solubility. . . . It has been found in many wild birds, fish, and mammals in the United States."

Fish and other aquatic animals have a fantastic ability to biologically concentrate chlorinated hydrocarbon pesticides in their bodies. A classic study by Hunt and Bischoff (1960) at Clear Lake, California, revealed living fish to contain a concentration of DDD more than 50,000 times the concentration applied to the lake for gnat control. Because living organisms concentrate pesticide residues, they are excellent indicators of pesticide pollution. Pesticide residues can be progressively magnified from the lowest to the highest animal forms in the food chain. Woodwell et al. (1967) in a study of a salt marsh in Long Island, New York, found DDT residues in the soil averaging more than 13 pounds per acre, while systematic sampling of various organisms from the vicinity showed concentrations of DDT increasing with trophic level through more than three orders of magnitude from 0.04 ppm in plankton to 75 ppm in a ring-billed gull. Highest concentrations occurred in fish and birds, although birds had 10 to 100 times more than fish.

Uptake and Biological Concentration in Fish. Both physiological and environmental factors are associated with the amount of pesticide residues fish will carry. Physiological factors include the ability of the fish to absorb and excrete pesticides. Environmental factors include the level of pesticide contamination of the aquatic environment and the availability of pesticides to fish.

Fish may pick up chlorinated hydrocarbon pesticides by eating contaminated food or by direct uptake from water via the gills. Some pesticides may also enter fish through the skin. Apparently uptake via the gills is very rapid, as appreciable amounts of DDT have been shown to enter fish within 5 minutes of exposure to water containing DDT (Premdas and Anderson, 1963). DDT and dieldrin are known to be fat soluble and to accumulate in fatty tissues. Residues of DDT and dieldrin have been reported from gill, muscle, liver, spleen, fat and gonad tissues (Holden, 1966) and probably occur throughout the bodies of residue-containing fishes. Fish can excrete as well as absorb pesticides and may reach an equilibrium with pesticides in the aquatic environment. Gakstatter and Weiss (1967) showed both the absorption of C^{14} labeled lindane, dieldrin, and DDT and their elimination from fish were related to the water solubility of these compounds. DDT is less soluble in water than dieldrin. Goldfish and bluegills eliminated more than 90 percent of the initial C^{14} labeled dieldrin within 2 weeks of exposure; however less than 50 percent of the DDT was eliminated within 32 days of exposure.

In theory different fish species may have different exposures to pesticides due to differences in habitat, food preference and exposure, hence species differences in residues could occur in fish collected in the same waters. Older fish would be expected to have experienced a longer period of exposure to pesticides. Length, weight, sex, species, and fat levels could be related to residue concentration levels. DDT and dieldrin are fat soluble and occur in fatty tissue, hence the amount of pesticide a fish has may be related to its fat content. Fish change in condition and fat level during the year in response to periods of stress, the availability of food, and spawning periods.

Where the greatest quantities of pesticides are applied, higher residues in fish should be expected to occur. Pesticide usage, precipitation, and surface run-off associated with pesticide pollution of waters fluctuate seasonally. Soil particles and organic materials may retain pesticide residues slowing their release into water. It has been suggested that water turbidity and high organic content might greatly reduce the availability of DDT and dieldrin to fish. All the above-mentioned factors bear upon the availability of pesticides to fish and therefore might be correlated with the pesticide residue levels of fish in the Wisconsin waters sampled in this study.

Toxicity of DDT, DDD, DDE, and Dieldrin to Animal Life

Direct Toxicity. Of the DDT analogs, DDT is most toxic with DDD less toxic, and DDE of apparently low toxicity. Dieldrin has a considerably higher toxicity than DDT. Typically these insecticides are less toxic to higher organisms than lower; insects and aquatic invertebrates are most sensitive and mammals, including man, are least sensitive.

The ensuing toxicity data has been gleaned from the literature summary prepared by McKee and Wolf (1963) unless specifically indicated. Men who have been exposed to DDT for as long as 6.5 years and consequently absorbed an average of 200 times as much DDT as the general population does in its food, have evidenced no chronic poisoning. The oral ingestion of 0.7 gram DDT will produce a sensation of burning or itching of the tongue, lips, and part of the face; at 1.0 gram, tremors and convulsions may commence. However, men have recovered from swallowing as much as 20 grams. DDT in the diet at the level of 35 milligrams per day in human volunteers for 18 months caused no toxic symptoms. The estimated fatal dose of DDT for a 154-pound man has been estimated at 30 grams and 5 grams for dieldrin. In several cases of dieldrin intoxication, it was concluded that contamination of water even with small quantities of dieldrin is dangerous. However, rats may be maintained for more than a year without injury on water containing 0.2 ppm of dieldrin, which concentration kills fish in a few hours.

Fish and other aquatic life are generally more susceptible to DDT than are land animals. The toxicity of DDT to fishes has been subjected to considerable study. Among the variables cited as affecting the toxicity of DDT in water are the type of water course and bottom, depth, vegetation, silt, turbidity, hardness, temperature, dissolved oxygen, organic content, species and age of fish and DDT formulation. Emulsions are most toxic, water wettable forms least toxic. These factors very likely affect the toxicity of DDT and dieldrin to other aquatic life.

Reported fatal concentrations of DDT in ppm in water are 0.1 for

Daphnia and tadpoles, 0.25 to 0.5 for crayfish, and 0.1 for stoneflies. At acutely toxic levels, the chlorinated hydrocarbons damage the central nervous system, causing instability, difficulty in respiration, and sluggishness in fish (Holden, 1965). Rainbow trout have been killed at concentrations of from 0.0237 to 0.074 ppm DDT. Bluegill fingerlings and bass yearlings at 0.01 ppm DDT, bluegill adults and goldfish at 0.1 ppm DDT and golden shiners at 0.5 ppm. Analysis of two Wisconsin waters where fish kills occurred following DDT spraying of elm trees were 0.073 and 2.2 ppm. Reported fatal concentrations of dieldrin in ppm in water are 0.012 for goldfish, 0.016 for brown trout, 0.04 for golden shiners and 0.006 for bass and goldfish.

Chronic Toxicity. Chronic effects of pesticide residues in animal life are difficult to measure, but nonetheless occur. The pesticide applicator cannot be assured pesticides have no harmful effects on fish and wildlife because dead fish, birds or mammals fail to appear following treatments.

Sublethal concentrations of chlorinated hydrocarbon pesticides may endanger fish indirectly by reducing the food supply, producing non-adaptive changes in behavior, or preventing or curtailing reproduction. Dimond (1967) showed that DDT contamination of streams following DDT application for spruce budworm control resulted in marked reductions in the amount and variety of invertebrate fauna, many of which are important fish foods; repopulation of all forms to previous levels as indicated by drift samples required three to four years. Warner et al. (1966) who showed that low levels of the chlorinated hydrocarbon pesticide, toxaphene, produced changes in the behavior of goldfish, concluded that low level environmental contamination by pesticides may have profound effects on aquatic life. Burdick et al. (1964) showed that DDT residues in adult lake trout could interfere with reproduction in certain New York state lakes. A DDT concentration in the ether extract of lake trout fry equivalent to 2.9 ppm or above in the weight of the fry resulted in mortality. Allison et al. (1964) found a critical period shortly after hatching when mortality was higher than normal in the offspring of cutthroat trout exposed to high DDT concentrations.

Fish, like insects, develop genetically based resistance to pesticides. Boyd and Ferguson (1964) found that mosquito fish from cotton-producing areas in the Mississippi delta were resistant to most commonly used chlorinated hydrocarbon insecticides. As much as a 300-fold resistance persists among the first few generation descendents of such resistant fish when reared in insecticide-free environments. Ferguson et al. (1964) demonstrated golden shiners, bluegills, and green sunfish from pesticide treatment areas displayed resistance to toxaphene, aldrin, dieldrin and endrin. Resistant fish tolerated pesticide concentrations of these pesticides in water from 36 to 70 times that of control fish of the same species during 36-hour median toleration limit tests.

Because of the combined effects of low chlorinated hydrocarbon pesticide solubility in water and high levels of resistance, Ferguson (undated) reported it is almost impossible to kill certain resistant fish, even with the more toxic pesticides. Resistance of fish to pesticides presents several problems, however. All species are not equally resistant. The unequal ability to resist toxic pesticides may disrupt species balance and cause the disappearance of desirable species from some waters. Although selection of a resistant species may permit exposed populations to survive, resistance may permit such high residue levels in fish as to render such fish dangerous as food to man as well as to other consumers. Ferguson found that green sunfish exposed to endrin in the laboratory contained from 11 to 26 ppm endrin in the edible portions; zero tolerances have been established for endrin due to its high toxicity.

FINDINGS

Range of DDT and Dieldrin Levels in Wisconsin Fish

Every sample of fish taken in Wisconsin or its boundary waters contained DDT or its analogs (Table 3, p. 36–40). In the whole fish samples DDT, DDD, and DDE averaged 23, 28, and 49 percent of the total DDT complex identified. Representation of the analogs constituting the DDT complex in individual samples, however, ranged from 0 to 100 percent DDT, from 0 to 78 percent DDD, and from 0 to 100 percent DDE. The concentration of DDT together with its analogs DDD and DDE, expressed on the "whole fish basis" ranged from 0.021 to 16.20 ppm and averaged 0.845 ppm. The concentration of DDT together with its analogs DDD and DDE expressed on the "fat basis" ranged from 0.222 to 534.6 ppm and averaged 27.15 ppm.

Nearly 70 percent of the fish samples contained dieldrin (Table 3). The concentration of dieldrin expressed on the "whole fish basis" ranged from trace amounts to 12.5 ppm and averaged 0.158 ppm. However, most samples containing dieldrin held less than 0.1 ppm. The concentration of dieldrin expressed on the "fat basis" ranged from 0.026 to 670.2 ppm and averaged 6.15 ppm. However, most dieldrin levels expressed on the fat basis were less than 1.0 ppm.

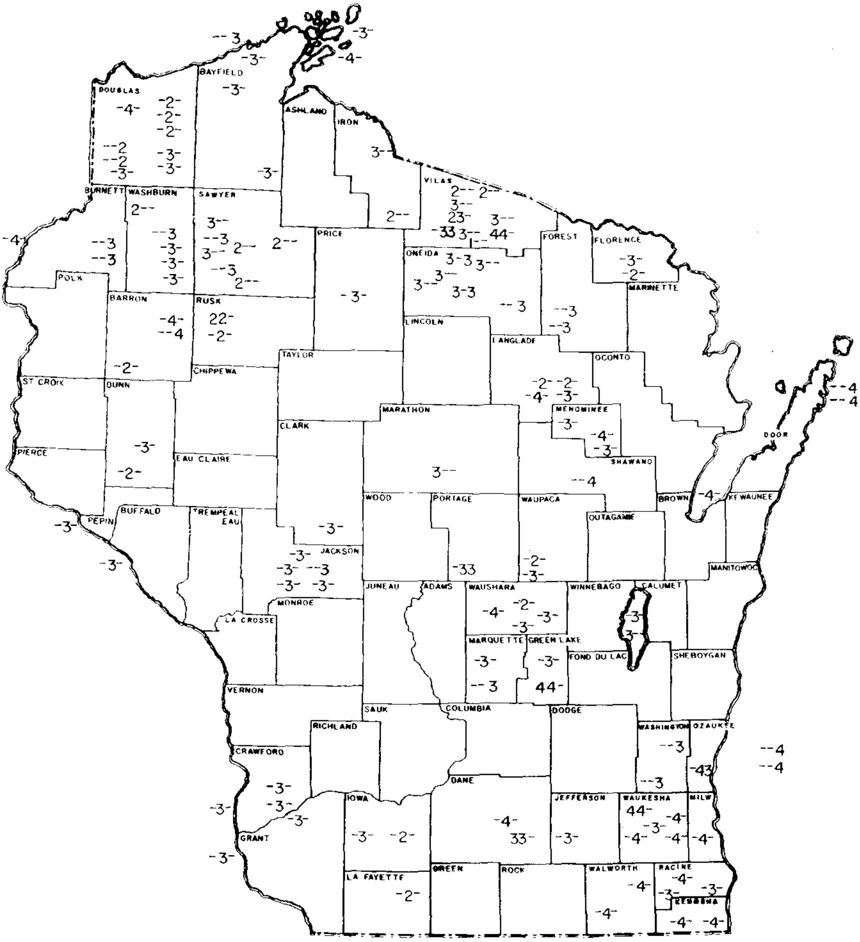
In general, dieldrin levels were much lower than DDT residues. A positive correlation ($r = 0.16$ with 529 d.f.) was noted between the levels of residues of DDT and dieldrin in fish samples from each of the various waters. However, this low correlation coefficient suggests little or no relationship between DDT and dieldrin residues in the samples.

Differences in Pesticide Residue Levels of Fish from Various Wisconsin Waters

There were distinct differences in the pesticide residue content of samples from different waters of Wisconsin (Figs. 1 and 2). The highest concentrations of DDT occurred in samples from Lake Michigan and southeastern Wisconsin where fish samples exceeded 1 ppm of the DDT complex expressed on the "whole fish basis". The lowest DDT residues were found in samples from forested northern Wisconsin, where most fish samples contained less than 1 ppm of the DDT complex expressed on the "whole fish basis". Exceptions to these general findings occasionally occurred where fish samples from a lake or stream might contain higher or lower DDT residues than occurred in fish samples from the surrounding area. Samples from Big Muskellunge Lake in Vilas County, for instance, contained DDT residues of far greater magnitude than were found in samples from Escanaba, High, Palmer, Plum, Sanborn, Star, Trout, and Upper Buckatobon Lakes of the same county. The reverse situation occurred in Waukesha County where samples from Pewaukee Lake contained lower DDT residues than occurred in nearby Pine and LaBelle Lakes. Fish samples taken from the lower portions of certain streams contained DDT residues many times those observed upstream, indicating sources of contamination between collecting sites.

Dieldrin when present in the samples generally occurred in amounts less than 0.1 ppm expressed on the "whole fish basis". However, fish samples from the Milwaukee and Pike Rivers, which pass through urban industrial areas, contained fish of very high dieldrin contamination. In the case of the Milwaukee River, upstream samples taken in Washington County contained no dieldrin, while downstream samples taken at Thiensville and Milwaukee held from 1.41 to 12.5 ppm dieldrin on the "whole fish basis"; this evidence indicated sources of contamination between collecting sites. Moderately high dieldrin levels were observed in certain samples taken from the Mississippi River and Lake Michigan.

Some of the fish samples taken in this study contained substances which were detected on the gas chromatograph but could not be identified. These substances most commonly occurred in samples from streams such as the Milwaukee and Mississippi Rivers which receive a variety of waste effluents from many sources. Certain samples also contained what appeared to be analogs of toxaphene.



LEGEND

1. Number indicates average magnitude of DDT and dieldrin residues in whole fish samples as follows:

Magnitude	PPM Pesticide
No samples taken	—
0	0
T	Trace
1	.001–.009
2	.010–.099
3	.100–.999
4	1.00–9.99

2. Position of number indicates year sampled as follows: 1965, 1966, and 1967.
3. Example:
   0–1 = 1965, 0
   1966, no samples taken
   1967, .001–.009 ppm pesticide

Figure 1. Average DDT levels in fish from 1965, 1966 and 1967 sampling locations.

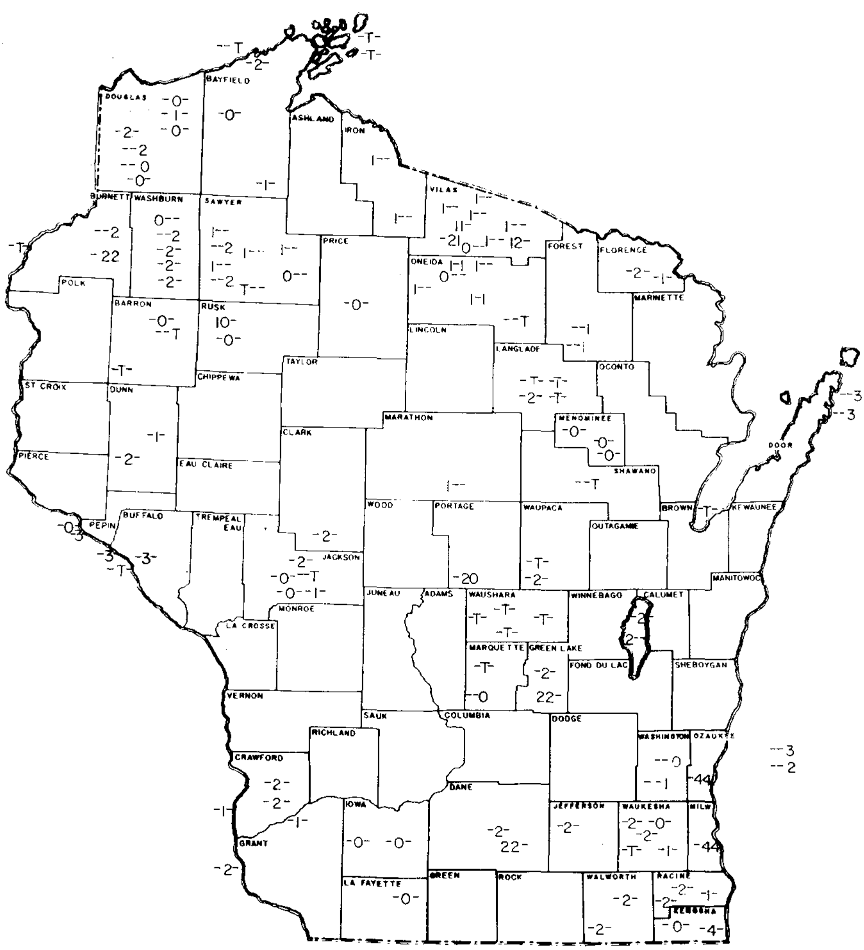


Figure 2. Average dieldrin levels in fish from 1965, 1966 and 1967 sampling locations. (See Figure 1 for legend)

Differences in Pesticide Residue Levels of Fish Samples Taken from the Same Waters

Pesticide levels did not differ consistently among the different species of fish sampled in this study. Where rough, pan, and game fishes were sampled from one location, residue values for all species were usually of similar magnitude. However, the fat content of samples of the different species of fish showed considerable variation. Generally speaking, carp, catfish, sheepshead, buffalo, lake trout, cisco, walleye, sauger, and white bass were the fatter fish (Table 1).

In theory, since DDT and other chlorinated hydrocarbon pesticides

TABLE 1

Fat Content of Fish Samples from the Surveys

Species		Percent Fat			
Common Name	Scientific Name	Letter Code	Low	Average	High
Sucker	*Catostomus* spp.	S	0.2	2.9	6.9
Redhorse	*Moxostoma* spp.	R	0.5	4.0	8.1
Buffalo	*Ictiobus* spp.	BF	6.6	8.4	10.1
Quillback	*Carpiodes cyprinus*	Q	—	5.3	—
Freshwater Drum	*Aplodinotus grunniens*	D	9.7	12.1	14.4
Carp	*Cyprinus carpio*	C	3.3	6.7	13.0
Largemouth Bass	*Micropterus salmoides*	LMB	0.4	2.2	5.7
Smallmouth Bass	*Micropterus dolomieui*	SMB	0.9	2.3	5.6
Bluegill	*Lepomis macrochirus*	B	0.4	3.0	6.6
Crappie	*Pomoxis* spp.	CR	2.4	3.7	4.9
Pumpkinseed	*Lepomis gibbosus*	P	1.0	2.1	3.5
Rockbass	*Ambloplites rupestris*	RB	1.5	2.4	4.7
Muskellunge	*Esox masquinongy*	M	1.1	3.7	6.0
Northern Pike	*Esox lucius*	NP	0.1	1.6	6.9
Bullhead	*Ictalurus* spp.	BU	0.7	3.0	4.0
Channel Catfish	*Ictalurus punctatus*	CC	2.6	9.0	16.3
Yellow Perch	*Perca flavescens*	YP	0.7	2.6	7.3
Sauger	*Stizostedion canadense*	SA	5.5	6.0	6.6
Walleye	*Stizostedion vitreum vitreum*	W	0.9	4.4	11.6
Cisco	*Coregonus artedii*	CI	2.4	6.0	12.8
Brook Trout	*Salvelinus fontinalis*	BT	1.2	3.7	8.9
Lake Whitefish	*Coregonus elupeaformis*	LW	—	1.8	—
Brown Trout	*Salmo trutta*	BR	1.1	4.3	9.8
Rainbow Trout	*Salmo gairdneri*	RT	0.2	6.2	13.9
Lake Trout	*Salvelinus namaycush*	LT	2.2	10.0	20.8
Splake	*Salvelinus* (*fontinalis* x *namaycush*)	SP	1.6	3.5	5.3
Coho Salmon	*Oncorhynchus kisutch*	CS	4.4	5.0	5.6
White Bass	*Roccus chrysops*	WB	5.8	7.5	9.1
Alewife	*Alosa pseudoharengus*	A	—	6.2	—
Trout-perch	*Percopsis omiscomaycus*	TP	—	1.5	—

TABLE 2

Correlation Coefficient for Percent Fat and DDT Levels in Whole Fish Samples from Selected Waters

County, Water, and Year of Samples	Correlation Coefficient (r)	Degrees of Freedom
Grant, Wisconsin River (1966)	−0.08	6
Jefferson, Lake Ripley (1966)	0.28	7
Dane, Lake Mendota (1966)	0.02	7
Waukesha, Lake Pewaukee (1966)	0.40	6
Winnebago, Lake Winnebago (1966)	−0.11	12
Waukesha, Lake LaBelle (1966)	0.31	19
Crawford, Mississippi River (1966)	0.87*	7

*Indicates significance at the .05 value. All other correlation coefficients are not significant at the .05 level.

are stored in the fat, fat fish should contain more pesticide. Whether this is the case is still to be determined. Correlation coefficients for fat percentages and DDT levels in fish samples from seven selected waters are presented in Table 2. In one group of samples there is a significant positive correlation between the amount of fatty tissue and DDT. In four groups of samples there are positive correlations and in two there are negative correlations, none of which are statistically significant. These data suggest a positive relationship between fat percentages and DDT levels in fish, but this relationship is not simple and direct, and other factors may be involved.

Comparison of 1965, 1966, and 1967 Pesticide Residue Values in Fish Samples

The surveys conducted over the three-year period 1965, 1966, and 1967 demonstrate a widespread and significant level of contamination in Wisconsin fishes with DDT and in a number of cases with dieldrin. These surveys do not, however, indicate the rate at which DDT and dieldrin levels may be building up or diminishing. Resurveys of DDT and dieldrin levels of fishes in the waters sampled in 1965, 1966, and 1967 will be necessary in the future to establish whether residues are increasing or decreasing.

Comparison of Residue Values with Those Taken in Wisconsin by Other Agencies

DDT and dieldrin levels found in Wisconsin fish samples processed by University of Wisconsin researchers, the Wisconsin Department of Agriculture, and the U. S. Bureau of Commercial Fisheries are of similar magnitude to residue values found by the Department of Natural Resources surveys taken in the same waters. University of Wisconsin researchers (Hickey et al. 1965) found total DDT levels in fishes collected in Lake Michigan off Door County to average 3.3 to 3.4 ppm in alewife regurgitated by gulls, 2.28 to 7.87 ppm in whole fish samples of chubs, 5.05 to 7.49 ppm in samples of whitefish muscle and 3.23 ppm in whitefish entrails. Residues found in market fish taken from Wisconsin waters in 1965 and reported by the State Department of Agriculture (pers. comm. covering 1965 samples) were 62.36 to 99.5 ppm total DDT and 0.31 to 0.576 dieldrin in the fat of raw unbrined Lake Michigan chubs, and 24.0 to 39.00 ppm total DDT and 0.296 to 0.592 ppm dieldrin in the fat of smoked Lake Michigan chubs.

Residue levels reported as ppm total DDT in whole fish samples from Wisconsin's coastal waters of Lake Michigan by the U. S. Bureau of Commercial Fisheries Laboratory (pers. comm.) covering 1965, 1966, and 1967 samples were 2.41 to 4.99 in alewife, 0.99 to 7.35 in American smelt, 0.90 to 0.97 in trout–perch, 1.25 for a single sample of lake herring, 5.29 to 15.00 for hoyi chub, 0.20 to 0.74 for fingerling lake trout, 0.35 to 0.50 for suckers, 3.58 for a single sample of carp, 0.39 to 4.72 for yellow perch, and 1.23 for a single sample of slimy sculpin. Dieldrin levels were not indicated for these samples. Residue levels reported as ppm total DDT in whole fish samples from Wisconsin's coastal waters of Lake Superior by the U. S. Bureau of Commercial Fisheries Laboratory were 0.07 to 0.51 in American smelt, 0.12 to 1.71 in alewife, 0.23 to 0.66 in stickleback, 0.64 to 2.15 in lake herring, 0.18 to 0.72 in lake whitefish, 0.13 to 1.62 in hoyi chub, 0.26 to 0.87 in round whitefish, 0.57 to 13.16 in lake trout, and 0.08 to 0.28 in slimy sculpin. Residue levels reported as ppm dieldrin in whole fish samples from Wisconsin's coastal waters of Lake Superior by the U. S. Bureau of Commercial Fisheries occurred in concentrations up to 0.07 in American smelt, 0.07 in alewife, 0.03 in stickleback, 0.03 in lake herring, 0.03 in lake whitefish, 0.09 in hoyi chub, 0.04 in round whitefish, 0.07 in lake trout, and 0.04 in slimy sculpin.

Comparison of Residue Values of Wisconsin Fish with Fishes from Other Regions of the United States

Little published information is available concerning the pesticide residue levels found in fish samples from other regions of the United States. However, recent investigations conducted in Massachusetts and the Great Lakes allow comparisons to be made between the levels of DDT and dieldrin found in Wisconsin fish as compared to fish from other areas.

In the present survey, total DDT residues in whole fish samples from Wisconsin ranged from 0.021 to 16.20 ppm. In a similar survey, conducted in Massachusetts by Tompkins et al. (1967), averaged total DDT levels for whole fish samples of nine species of fish from major rivers and tributaries of Massachusetts ranged between 0.17 and 11.64 ppm. Averaged total DDT levels for whole fish samples of various species from each of the Great Lakes as reported by Carr and Reinert (1968) ranged from 0.27 to 10.40 ppm for Lake Michigan, 0.15 to 7.77 for Lake Superior, 0.65 to 6.90 ppm for Lake Huron, 0.21 to 1.89 ppm for Lake Erie, and 0.40 to 4.32 ppm for Lake Ontario. These data indicate that the DDT residue levels found in Wisconsin fish are within the range of magnitudes found in samples from Massachusetts and the Great Lakes region.

Dieldrin levels in whole fish samples in the present survey ranged from 0.00 to 12.5 ppm, but most samples held less than 0.1 ppm dieldrin. Averaged dieldrin levels for whole fish samples of various species from each of the Great Lakes as reported by Carr and Reinert (1968) ranged from 0.03 to 0.29 ppm for Lake Michigan, 0.02 to 0.05 ppm for Lake Superior, 0.02 to 0.12 for Lake Huron, 0.00 to 0.14 for Lake Erie and 0.02 to 0.28 for Lake Ontario. These data indicate that levels of dieldrin residues in Wisconsin and Great Lakes fishes are generally of low magnitude. The exception being those samples taken in the Milwaukee and Pike Rivers of southeastern Wisconsin which contained dieldrin in whole fish samples ranging from 1.10 to 12.5 ppm. To our knowledge, dieldrin residues in fish samples reported from the lower Milwaukee River and the Pike River are the highest reported in the literature to date.

Sources of DDT and Dieldrin Residues in Wisconsin Fish

It is an established fact that pesticide residues can be transported from areas of application by wind drift, water movement, and movement of residue-containing birds and animals. Bailey and Hannum (1967) found persistent pesticides distributed through every segment of selected California aquatic environments and reported that in practically all cases, pesticide concentrations were related to local agricultural development practices and to pesticide use.

Some pesticides may be carried into Wisconsin via wind from other areas. The amount of DDT and dieldrin in Wisconsin fish, however, appears to bear a close relationship to pesticide use in the watershed. The higher residue values were observed in various urbanized, outdoor recreation, and agricultural locations known or suspected to be areas of frequent pesticide use. Fish samples from known pesticide treatment areas contained as much as 250 times the amount of DDT found in fish from waters where little or no pesticide use is known.

In general the amounts of DDT and dieldrin found in fish samples in southeastern Wisconsin are greater than those found from other parts of the state. We believe greater pesticide residues occur in fish here because pesticide use for household, lawn, garden, shrubs, trees, commercial and industrial uses are more intensive in this populated area of the state.

Fish samples taken in Lake Michigan waters in the vicinity of Door County contained high DDT levels as did fish from other areas of Lake Michigan. Door County contains the bulk of Wisconsin's 10,000 acres of cherry orchards. Here the use of chlorinated hydrocarbon pesticides has been estimated to be 30 tons of DDT, 15 tons of methoxychlor and 15 tons of DDD annually (Hickey et al., 1965). A larger cherry-, apple-, and peach-growing region is located on the eastern coast of Lake Michigan in the state of Michigan. Without question large quantities of DDT have also been used in Michigan orchards. Cities located on streams draining into Lake Michigan which have conducted sizable DDT spray programs to control Dutch elm disease are also suspected to be major sources of DDT pollution in Lake Michigan. It is very likely that DDT use in the Milwaukee area has contributed to the build-up of DDT in Lake Michigan fish.

DDT levels in fish from northern Wisconsin were generally much lower than those found in the Southeast. Exceptions are fish samples from such areas as Big Muskellunge Lake in Vilas County, which has a public campground treated in the past with DDT for insect control.

High dieldrin levels in fish samples taken in the Pike and lower Milwaukee Rivers have been traced to spot polluting sources. In the case of the Pike River a source of dieldrin pollution was traced to an industry that packaged dieldrin in cans. This industry subsequently acted to prevent dieldrin pollution of the stream. A major dieldrin polluting source for the lower Milwaukee River was found to be a woolen mill which used raw wool treated with dieldrin and moth-proofed its manufactured woolen goods with dieldrin. Officials of the woolen mill were taken to court and ordered to cease discharging dieldrin into the Milwaukee River. Details of this investigation are contained in a report in preparation.

It must also be pointed out that environmental conditions within a stream or lake system may influence the magnitude of DDT and dieldrin residues in fish. DDT residue levels were lower in fish samples from Pewaukee Lake than occurred in fishes in nearby Pine and LaBelle Lakes. All three lakes have shorelines intensively developed as homesites. All occur in an area where elms were treated with DDT to prevent Dutch elm disease, and all have properties which have received treatments of DDT for the control of mosquitoes and other insects. Pewaukee Lake differs from the other lakes by being more shallow, more fertile, and having extensive mud flats covering most of the lake bottom. It is possible DDT is rapidly adsorbed by the extensive sediments of fine texture and high organic content which underlie most of Pewaukee Lake, partially preventing the release of these pesticides into the aquatic environment where fish can biologically concentrate them.

DISCUSSION

Significance of DDT and Dieldrin Residues in Wisconsin Fish

Immediate Concerns

Of immediate concern is the possible effect of pesticide residues on fish reproduction. The Department of Natural Resources has conducted an investigation into the effects of DDT residues on walleye reproduction in ten different waters of the state. These studies have failed to prove DDT inhibits reproduction in the range of residue levels encountered (Kleinert and Degurse, 1968). Studies have recently revealed, however, that the DDT content of salmon eggs from Lake Michigan is approaching concentrations which Burdick et al. (1964) found prohibited the reproduction of lake trout in New York state. Studies are underway in Michigan to evaluate the effect of DDT on coho salmon reproduction in Lake Michigan. The possibility that DDT concentrations may have already reached levels harmful to salmon and lake trout in Lake Michigan is shocking in view of the lake's immense size (22,400 square miles) and the importance of the sport and commercial fishery to the region.

It is not the intent of this report to make final statements regarding the suitability of Wisconsin fishes as human food. Apparently neither the State Department of Agriculture nor the health authorities believe there is any great health hazard in consuming Wisconsin fish. By law, the U. S. Food and Drug Administration is responsible for seeing that the food supplies of this nation are safe, clean, and wholesome. With respect to pesticide residues the FDA sets safe limits on the amounts that may remain on food crops. Based on the results of many tests a tolerance is established well within the concentration of safety, even though a larger amount would still be considered safe. Official FDA tolerances through December 31, 1967 (National Agricultural Chemicals Association news, Vol. 26, No. 3) for many of the common foods we eat were as follows: 7 ppm of the DDT complex and 0.1 ppm dieldrin for apples, cherries, grapes, plums, strawberries, asparagus, cucumbers, onions, and tomatoes; 7 ppm of the DDT complex in the fat of meat from cattle, hogs, and sheep; and 1 ppm of the DDT complex and 0.1 ppm dieldrin in potatoes. Thus far tolerance levels have not been set for fish used as human food. However, DDT residues in whole fish samples from certain Wisconsin inland waters and Lake Michigan approached or exceeded the DDT tolerances established for many other foods. Dieldrin residues in fish samples from the lower Milwaukee River and Pike River in Kenosha County were considerably higher than the dieldrin tolerances established for other foods.

Recent studies have shown pesticide residues may be partially removed when fish are prepared for human consumption. Reinert (1968) found that filleting Lake Michigan chubs did not reduce the DDT concentration to any appreciable extent; however, smoking, pan frying and broiling caused a marked reduction in DDT concentration, due primarily to the rendering out of the oil. On the other hand, Reinert found that the filleting operation on Lake Michigan perch removed most of the DDT since most of the oil in perch was found in the scrap; cooking the fillets had little effect on pesticide concentration. These results confirmed the relationship between oil removal and the lowering of pesticide levels.

Long-term Concerns

Of ultimate concern are the threats which the long-term build-up of pesticide residues in the environment present. Biologically speaking, pollution of water by pesticides in any form is undesirable. Long-term pollution by pesticides which degrade slowly and accumulate in living tissue is especially feared, because the ecological effects may be so complex that they are almost impossible to trace. Crow (1967) has cautioned that in a complex industrial society, there is always the possibility that newly developed chemicals will have an unexpected deleterious effect on the hereditary factors of man and other animals. If these effects result from gradual accumulation of small amounts over a period of years, they are exceedingly difficult to discover.

In spite of the progress of modern technology, science as yet has only a crude understanding of the living environment. Extensive pretesting usually will not uncover long-term residual effects of pesticides on the living environment. The use of any persistent pesticide remains a calculated risk. Science has already shown chlorinated hydrocarbon pesticides to interfere with fish reproduction, behavior, and hereditary factors. Further, these residues may be harming a variety of animal life in many subtle ways, which will only become apparent through intensive research. To continue to use DDT and dieldrin in the face of the present level of contamination would seem to be an invitation to disaster.

Elms being sprayed with DDT in Port Washington during the early spring to kill beetles that carry Dutch elm disease. (Photo by Vern Arendt, Port Washington) ▶

RECOMMENDATIONS

Because of the past damage and future threat imposed by the use of persistent pesticides, no report of this type is complete without restating and amplifying warnings and proposing solutions to the problem. The professional conservationist and the knowledgeable layman have no alternative but to repeat the facts and essential recommendations until appropriate action is taken.

Guiding Principles

The President's Science Advisory Committee (1963a) recommended as a goal the elimination of persistent toxic pesticides. Today there is little evidence this goal is being met. The trend is toward increasing use of pesticides, many of which are of the persistent variety.

Persistent chemicals applied to one area may pollute an environment many miles away. Therefore the decision to apply such chemicals must not be left solely with limited or local interests, but must be decided according to the general public welfare. This problem has been recognized and expressed by the Environmental Pollution Panel of the President's Science Advisory Committee which recommended these guiding principles for restoring the quality of our environment (1963b): The public should come to recognize individual rights to quality of living, as expressed by the absence of pollution, as it has come to recognize rights to education, to economic advance, and to public recreation. The responsibility of each pollutor for all forms of damage by his pollution should be effectively recognized and generally accepted. There should be no "right" to pollute.

In recent years Wisconsin has been concerned with the dangers of pesticide pollution. One of the early publications expressing this concern was prepared by the Governor's Special Committee on Chemicals and Health Hazards (State of Wisconsin, 1961). The latest effort concerns a report in preparation by a Working Group of the Waters Subcommittee in the Natural Resources Council of State Agencies. These and other similar efforts have acknowledged pesticide pollution problems in Wisconsin and have offered recommendations for dealing with the problem. We endorse the guiding principles established by the President's Science Advisory Commitee and the Governor's Special Committee on Chemicals and Health Hazards and urge the following specific recommendations be implemented.

Specific Recommendations

1. **Prohibit Surface Water Pollution by Pesticides:** We believe that DDT, dieldrin, and other persistent pesticides should not be used in

a manner that would permit them to reach surface waters. This prohibition would eliminate the current methods of use of DDT for control of Dutch elm disease. Current research* has demonstrated that DDT and methoxychlor do reach surface waters via run-off shortly after being applied to urban areas. Passage of legislation, the development of administrative codes, and their implementation are sorely needed to protect the aquatic environment.

2. **Record Pesticide Use:** The locations of use and amounts of persistent pesticides being applied in Wisconsin should be a matter of strict public record. It is recommended that a workable method for establishing records of persistent pesticide use in Wisconsin be immediately developed and implemented.

3. **Continue Pesticide Investigations:** Continued investigations into the effects of pesticides on the environment are recommended. Under existing conservation laws, pollutors can be punished and prohibited from further pollution. Enforcement of these laws, however, requires monitoring, detection and the gathering of evidence which will stand up in court. All of these functions demand highly trained personnel, laboratory services, and an adequate operating budget. It is recommended these functions be supported and maintained. Without the trained personnel and laboratory services needed to detect pesticide pollution, control of pesticide pollution is impossible.

4. **Continue Monitoring Pesticide Residues:** Continued research into specific pesticide pollution problems is essential to pesticide pollution abatement in Wisconsin. The Department of Natural Resources has carried on a pesticide residue research program since 1965. This program included the present study, investigations into the effect of DDT residues on walleye reproduction in Wisconsin (Kleinert and Degurse, 1968), and most recently an investigation into the sources and seasonal variation of chlorinated hydrocarbon pesticide residues in the Milwaukee River watershed and other waters. The last-mentioned studies, which have identified pollution sources associated with the pesticide contamination of fish, should be continued. The current monitoring study of pesticide residues in Wisconsin fish should be continued to determine if DDT and dieldrin residue levels in fish are declining, remaining the same, or increasing in magnitude. This surveillance would aid in identifying point sources of pesticide pollution. Specific studies should be undertaken to determine the effects of pesticide residues as well as other forms of persistent chemical

* The findings of this investigation are contained in a report in preparation by the Water Resources Research Section of the Wisconsin Department of Natural Resources.

toxicants on fish and other forms of animal life whenever problem conditions are identified.

Studies should also be undertaken to determine the amount of airborne pesticides entering Wisconsin from outside the state and to measure pesticide drift from treatment areas within the state. This is a most important aspect of the pesticide pollution problem in need of investigation.

5. **Educate Citizenry on Dangers:** It is recommended that conservation agencies, including the Wisconsin Department of Natural Resources, do a better job of educating the citizens to the dangers of persistent pesticides. Such a campaign is necessary because the advertisers, manufacturers and sales promoters have conditioned the public into believing that every insect should be killed, every lawn, garden, tree, or shrub treated, and every home equipped with an aerosol bug bomb or insecticide strip. The thoughtless use and overuse of pesticides has become a way of life for many of our citizens. Highly toxic insecticides are stocked on grocery shelves, at filling stations, and other commercial outlets while many relatively harmless drugs cannot be purchased without a prescription. In truth, pesticides should not be misused, overused, or used at all unless absolutely necessary.

6. **Develop Alternative Insect Control Methods:** Control of insect pests should go beyond the routine application of chemicals. Sanitation, crop rotation, improving growth conditions for plants, and developing pest-resistant varieties are alternatives to pesticide applications which should be more fully explored.

The presence of some insects is necessary to a balanced ecosystem. An acceptance of certain insects is the best attitude conservationists could instill in the citizenry. Citizens should not be driven into the belief promoted by the advertisers that an insect-free environment is the only acceptable environment.

When pesticides must be used, Wisconsin should insist that nonpersistent pesticides be substituted for persistent ones wherever possible. It may be necessary to prohibit or restrain the use of certain pesticides such as DDT and dieldrin, resulting in temporary economic losses. These sacrifices are necessary if the quality of the environment is to be maintained. In the long run such sacrifices are a small price to pay for a clean environment.

7. **License Pest Control Operators:** Commercial pesticide operators should demonstrate a knowledge of the nature of the pesticides used, their correct application and the laws and rules governing their use. A licensing system should be implemented to insure commercial pesticide operators have acquired this knowledge.

8. **Establish a Pesticide Review Board:** A pesticide review board should be established in Wisconsin to supervise pesticide use in the state. This board should include representatives from the State Departments of Natural Resources, Agriculture and Health and Social Services. They should appoint an advisory council of technical or professional persons consisting of representatives from each of the state departments involved, from one or more of Wisconsin's institutions of higher learning, and such other members as the board may designate. The advisory council would have the function of assisting the board, particularly in obtaining scientific data and coordinating pesticide regulatory and enforcement functions.

Under present laws, programs and attitudes there is no guarantee that the chlorinated hydrocarbon pesticides or other persistent toxic chemicals will not increase in the environment. Conservation measures to deal with residue problems must take into account the possibility of increased chemical pollution, not only from pesticides, but from many other chemicals now in use. The fact that toxic residues are becoming a worldwide problem of increasing seriousness should not deter the people of Wisconsin from taking action. Wisconsin has the opportunity to become a leader among the states in controlling toxic residues in the environment.

TABLE 3

Magnitude of DDT and Dieldrin Residues in Fishes from Various Wisconsin Waters

County	Water	Year and Laboratory*	Species Sampled**	Average PPM Pesticide in Whole Fish Samples**	
				DDT Complex	Dieldrin
Ashland	Lake Superior	1967 DNR	2CI, BR, 6LT	1.61	T
Barron	Big Moon Lake	1965 WARF	BT	Interference	0.009
	Big Moon Lake	1966 DNR	2 RT	Interference	T
	Brill River	1966 DNR	2S, BR	1.168	0
	Brill River	1967 DNR	MIX, BR	1.415	T
Bayfield	Bibon Lake	1966 DNR	NP, YP	0.288	0.066
	Lake Superior	1967 DNR	CS	0.258	T
	Namekagon Lake	1966 DNR	B, RB, NP, BU, NP	0.762	0.008
	Unnamed Lake	1966	LMB	0.410	0
Buffalo	Mississippi River	1966 DNR	C, LMB, B, 2CC, 2NP, YP, W, WB	0.612	0.073
Burnett	Big McKenzie Lake	1967 DNR	LMB, MIX	0.202	0.022
	Lipsett Lake	1966 DNR	LMB, B, RB, BU, NP, YP, W	0.111	0.070
	Lipsett Lake	1967 DNR	C, LMB	0.139	0.038
	St. Croix River	1966 DNR	R, SMB, 2NP	4.361	T
Calumet	Lake Winnebago	1965 WARF	S, 2YP, 2W	0.271	0.012
Clark	Arbutus Lake	1966 DNR	LMB, SMB, W	0.190	0.012
Crawford	Mississippi River	1966 DNR	R, C, SMB, B, CR, NP, BU, CC, SA	0.339	0.004
	Kickapoo River	1966 DNR	S, 2R, 2BF, Q, C, CC, W	0.337	0.030
Dane	Lake Kegonsa	1965 WARF	S, 2C, 2YP, 2W	0.901	0.011
	Lake Kegonsa	1966 DNR	C, 3B, NP, YP, W	0.689	0.027
	Lake Mendota	1966 DNR	C, 2LMB, 2B, NP, 2BU, YP	2.089	0.016
Door	Lake Michigan	1967 DNR	2BT, BR	5.28	0.256
	Green Bay	1966 DNR	RT	6.57	T
Douglas	Amnicon Lake	1966 DNR	LMB, M, W	1.244	0.027
	Brule River	1966 DNR	3S, BT, BR, 3RT	0.075	0.003
	St. Croix River	1966 DNR	S, R, LMB, NP, W	0.322	T
	St. Croix River	1967 DNR	3S, 3B, CR	0.082	0.015
	Sand Lake	1966 DNR	S, LMB, B, NP, BU, YP	0.215	0.004
	Simms Lake	1966 DNR	S, MIX, LMB, YP, 2RT	0.206	T

TABLE 3—(Continued)

County	Water	Year and Laboratory*	Species Sampled**	Average PPM Pesticide in Whole Fish Samples**	
				DDT Complex	Dieldrin
Dunn	Knight Creek	1966 DNR	BT, BR	0.086	0.010
	Menominee Lake	1966 DNR	LMB, B, NP, BU, YP, W	0.119	0.003
Florence	Pine River	1966 DNR	BT, BR	0.103	0.005
	Popple River	1966 DNR	BT	0.085	0.007
Forest	Lake Lucerne	1966 DNR	MIX, NP, W	0.103	0.005
	Mole Lake	1967 DNR	S, MIX, NP, BU, YP, W	0.322	0.007
Grant	Wisconsin River	1966 DNR	C, R, SMB, 2NP, CC, 3MIX	0.351	0.009
	Mississippi River	1966 DNR	C, D, LMB, MIX, NP, CC, W	0.302	0.031
Green Lake	Big Green Lake	1965 WARF	LT, SP	1.110	0.011
	Big Green Lake	1966 DNR	CI, LT, SP	1.151	0.120
	Upper Fox River	1966 DNR	CC	0.154	0.012
Iowa	Birch Lake	1966 DNR	3RT	0.186	0
	Cox Hollow Lake	1966 DNR	LMB, B, NP, BU	0.067	0
Iron	Flambeau Flowage	1965 WARF	S, CR, 2W	0.075	0.005
	Gile Flowage	1965 WARF	2CR, W	0.100	0.004
Jackson	Halls Creek	1966 DNR	2S	Interference	Interference
	Lake Arbutus	1966 DNR	B, NP, CC	0.216	0.018
	Perry Creek	1966 DNR	S, BR	0.805	0
	Perry Creek	1967 DNR	MIX	0.577	T
	Robinson Creek	1966 DNR	S, BT, BR	0.636	0.002
Jefferson	Lake Ripley	1966 DNR	G, S, LMB, B, 2NP, BU, YP, W	0.430	0.026
Kenosha	Fox River	1966 DNR	C, S, SMB, NP, BU, YP	1.80	0
	Pike River	1966 DNR	C, S, A	3.786	1.48
Lafayette	Yellowstone Lake	1966 DNR	2C, LMB, B, NP, YP	0.081	0
Langlade	Eau Claire River	1966 DNR	2S, 2BT	0.273	0.014
	Oconto River	1966 DNR	S, BT, 3BR	0.638	0.020
	Spring Brook	1966 DNR	BT	1.52	0
	Upper Elton Creek	1966 DNR	BT	0.096	T
	Upper Evergreen River	1966 DNR	BR	0.078	T
Marathon	DuBay Lake	1965 WARF	C, S, W	0.131	0.007
Marquette	Chapman's Creek	1967 DNR	MIX	0.240	0
	Lawrence Creek	1966 DNR	S, BT	0.113	T
Menominee	Lower Elton Creek	1966 DNR	BT	1.055	0
	Lower Evergreen River	1966 DNR	2BT, BR	0.778	0
	Wolf River	1966 DNR	R	0.404	0

TABLE 3—(Continued)

County	Water	Year and Laboratory*		Species Sampled**	Average PPM Pesticide in Whole Fish Samples**	
					DDT Complex	Dieldrin
Milwaukee	Milwaukee River	1966	DNR	C, S	2.22	1.17
	Milwaukee River	1967	DNR	2S	Interference	10.00
Oneida	Madeline Lake	1965	WARF	S, 2M, YP, 2W	0.181	0.001
	Madeline Lake	1966	DNR	LMB, MIX, M	0.288	0.004
	Madeline Lake	1967	DNR	B, W	0.403	0.004
	Minocqua Lake	1965	WARF	NP	0.40	0
	North Pickerel Lake	1965	WARF	S, YP, 2W	0.149	0.004
	Squirrel Lake	1965	WARF	S, 2M, YP, W	0.181	0.002
	Tomahawk Lake	1965	WARF	S, YP, 2W	0.312	0.004
	Tomahawk Lake	1966	DNR	C, NP, W	0.313	T
	Tomahawk Lake	1967	DNR	B, 2W, LT	0.409	0.007
	Wisconsin River	1967	DNR	MIX, CR	0.221	T
Ozaukee	Milwaukee River	1966	DNR	C, S, P, BU	1.303	2.284
	Milwaukee River	1967	DNR	2C, S, B, P, BU	Interference	7.45
Pepin	Mississippi River	1966	DNR	2C, MIX, LMB, B, NP, CC, YP, W	0.941	0.071
Portage	Buena Vista Creek	1966	DNR	S, BT	0.132	0.009
	Pickerel Lake	1967	DNR	NP	0.640	0
Price	Cranberry Lake	1966	DNR	LMB, B, 2CR, NP	0.476	T
Racine	Browns Lake	1966	DNR	C, LMB, B, YP	0.956	0.062
	Eagle Lake	1966	DNR	LMB, 2B, NP, 2BU, YP, W	0.150	0.006
	Fox River	1966	DNR	C, S, SMB, BU, YP, W	1.836	0.010
Rusk	Hemlock Creek	1966	DNR	BT	0.082	0
	Murphy Flowage	1965	WARF	S, 2LMB, 2B, 2YP	0.035	0.001
	Murphy Flowage	1966	DNR	S, LMB, B, NP, BU, YP	0.055	T
Sawyer	Big Sissabagama Lake	1967	DNR	W	0.145	0.010
	Chippewa Flowage	1965	WARF	S, 2YP, ZW	0.059	0.002
	Durphee Lake	1967	DNR	B	0.103	0.032
	Knutson Lake	1965	WARF	S, 2LMB, 2YP	0.037	T
	Court Oreilles Lake	1965	WARF	2M	0.660	0.002
	Moose Lake	1965	WARF	R, RB, YP, 2W	0.063	0.002
	Windigo Lake	1965	WARF	S, 2YP, 2W	0.143	0.001
Shawano	Little Wolf River	1967	DNR	S, BT	1.711	T

TABLE 3—(Continued)

County	Water	Year and Laboratory*		Species Sampled**	Average PPM Pesticide in Whole Fish Samples**	
					DDT Complex	Dieldrin
Vilas	Big Muskellunge Lake	1965	WARF	S, MIX, 3M, 2W	1.315	0.007
	Big Muskellunge Lake	1966	DNR	4M, 5W	2.719	0.002
	Clear Lake	1966	DNR	MIX, M	0.138	0.002
	Content Lake	1965	WARF	YP	0.08	0
	Crystal Lake	1967	DNR	SP	0.304	0.003
	Escanaba Lake	1965	WARF	S, 2YP, 2W	0.072	0.003
	Escanaba Lake	1966	WARF	LMB, P, M, NP, YP, W	0.134	0.003
	High Lake	1965	WARF	S, B, CR, 2W	0.296	0.004
	Little Trout Lake	1967	DNR	W	0.344	T
	Pallette Lake	1966	DNR	S, CI, SP	0.115	0
	Pallette Lake	1966	WDA	SP	0.156	0
	Palmer Lake	1965	WARF	2CR, 2YP, 2W	0.078	0.002
	Plum Lake	1965	WARF	S, 2RB, 2W	0.275	0.005
	Sanbom Lake	1965	WARF	S, NP, 2YP	0.074	0.002
	Star Lake	1965	WARF	S, 2YP, 2W	0.175	0.004
	Trout Lake	1966	DNR	YP, W, CI, LW, LT	0.618	0.018
	Trout Lake	1967	DNR	RB, W, LT	0.424	0.009
	Upper Buckatobon Lake	1965	WARF	S, YP, 2W	0.389	0.006
	Wisconsin River	1966	DNR	MIX, YP, W	0.172	0.003
Walworth	Lake Geneva	1966	DNR	S, LMB, B, BU, YP, CI	2.242	0.039
	Honey Creek	1966	DNR	C, S, LMB	1.086	0.091
Washburn	Bear Creek	1965	WARF	NP	0.084	0
	Beaver Brook	1966	DNR	S, BT, 2BR	0.162	0.076
	Beaver Brook	1967	DNR	S, NP, MIX	0.188	0.094
Washington	Beaver Brook	1967	DNR	LMB, NP	0.101	0.007
	Milwaukee River	1967	DNR	C, R, LMB, CR, MIX, NP, BU	0.098	0
	Pike Lake	1966	WDA	8W	0.55	0.013
Waukesha	Fox River	1966	DNR	C, S, P, NP, BU, YP	1.139	T
	Golden Lake	1966	WDA	4W	1.12	0.006
	Lake LaBelle	1965	WARF	S, LMB, 2YP, 2W	3.02	0.008
	Lake LaBelle	1966	DNR	C, S, LMB, 3B, NP, 2YP, 6W	3.86	0.012
	Nagawicka Lake	1966	DNR	W	0.126	0.025
	Upper Nemahbin Lake	1966	DNR	W	2.63	T
	Pewaukee Lake	1966	DNR	C, S, LMB, SMB, B, BU, YP, W	0.515	0.003
	Pine Lake	1966	DNR	C, LMB, B, NP, BU, YP, W, CI	3.55	0.003

TABLE 3—(Continued)

County	Water	Year and Laboratory*		Species Sampled**	Average PPM Pesticide in Whole Fish Samples**	
					DDT Complex	Dieldrin
Waupaca	Crystal River	1966	DNR	NP	0.330	0.017
	Emmon Creek	1966	DNR	BT	0.240	T
Waushara	Big Roche-a-Cri Creek	1966	DNR	BT	1.186	T
	Lake Winnebago	1966	DNR	NP, TP	0.170	0
	Pine River	1966	DNR	2S, 2BR	0.104	T
	White River	1966	DNR	S, BR	0.296	T
Winnebago	Lake Winnebago	1966	DNR	D, LMB, B, CR, P, 2NP, BU, CC, 2YP, SA, W, WB	0.313	0.010
?	Lake Michigan	1967	DNR	2CS	12.19	0.273

*Letter designations for the laboratories are as follows: WARF (Wisconsin Alumni Research Foundation Laboratory), WDA (Wisconsin Department of Agriculture Laboratory), and DNR (Department of Natural Resources Nevin Laboratory).

**Species letter symbols are defined in Table 1. MIX indicates a combined sample of two or more species. Numbers preceding letter symbols indicate the number of samples of each species. Interference indicates the reading from the gas chromatograph was obscured by interfering substances.

LITERATURE CITED

ALLISON, D. T.
1964. Some chronic effects of DDT on cutthroat trout. *In:* U. S. Fish Wildl. Serv. Res. Rept. 64, pp. 1–28.

APPLE, J. W.
1967. Insecticide recommendations and usage in Wisconsin agriculture. Trans. Citizens Conf. on Pesticides, sponsored by Citizens Natural Resources Assoc. of Wis. and the Dept. of Botany, Univ. of Wis., Madison, April 16, 1966. 47 p.

BAILEY, T. E. AND J. R. HANNUM
1967. Distribution of pesticides in California. J. Sanitary Eng. Div., Proc. Amer. Soc. Civil Eng. 1967, pp. 27–43.

BOYD, C. E. AND D. E. FERGUSON
1964. Spectrum of cross-resistance to insecticides in mosquito fish, *Gambusia affinis*. Mosquito News 24:19–21.

BURDICK, G. E., E. J. HARRIS, H. J. DEAN, T. M. WALKER, JACK SKEA, AND DAVID COLBY
1964. The accumulation of DDT in lake trout and the effect on reproduction. Trans. Amer. Fish. Soc. 93(2):127–136.

CARR, J. F. AND R. E. REINERT
1968. DDT and dieldrin levels in Great Lakes fish. Eleventh Conf. on Great Lakes Research, Milwaukee, Wis. April 18–20, 1968. (General outline of paper presented in Center for Great Lakes Studies Special Report No. 3, Univ. of Wisconsin, Milwaukee, pp. 7–8.)

COULSON, D. M.
1962. Pesticides in clothing. Pesticide Research Bull., Stanford Research Inst., Vol. 2(4):1–2.

CROW, J. F.
1967. Genetic aspects of insecticide resistance. Trans. Citizens Conf. on Pesticides, sponsored by the Citizens Natural Resources Assoc. of Wis. and the Dept. of Botany, Univ. of Wis., Madison, April 16, 1966. 47 p.

DIMOND, J. B.
1967. Pesticides and stream insects. Maine Forest Serv., Augusta, Maine. Bull. No. 23, 21 p.

FERGUSON, D. E., D. D. CULLEY, W. D. COTTON, AND R. P. DODDS
1964. Resistance to chlorinated hydrocarbon insecticides in three species of freshwater fish. BioScience 14 (11):43–44.

FERGUSON, D. E., J. L. LUDKE, J. P. WOOD, AND J. W. PRATHER
1965. The effects of mud on the bioactivity of pesticides on fishes. J. Miss. Acad. Sci. 11:219–228.

FERGUSON, D. E.
(Undated) The ecological consequences of pesticide residues in fishes. Dept. of Zoology, Miss. State Univ., State College, Miss., 6 p.

GAKSTATTER, J. H. AND C. H. WEISS
1967. The elimination of DDT—C^{14}, dieldrin—C^{14}, and lindane—C^{14} from fish following a single sublethal exposure in aquaria. Trans. Amer. Fish. Soc. 96:301–307.

HICKEY, J. J., J. A. KEITH AND F. B. COON
1965. An exploration of pesticides in a Lake Michigan ecosystem. Completion Rept. (Part 1) for contract 14–16–0008–659 submitted to Bur. of Sport Fish. and Wildl., Fish and Wildl. Serv., U. S. Dept. of the Int., 30 p.

HILL, D. W. AND P. L. MCCARTY
1967. Anaerobic degradation of selected chlorinated hydrocarbon pesticides. Water Pollution Control Fed., Washington, D.C. pp. 1259–1277.

HOLDEN, A. V.
1965. Contamination of fresh water by persistent insecticides and their effects on fish. Ann. Appl. Biol. 55(2):332–335.
1966. Organochlorine insecticide residues in salmonid fish. Pesticides in the environment and their effects on wildlife. J. Appl. Ecol. 3:45–53 (Suppl., June 1966).

HUNT, E. G. AND A. I. RISCHOFF
1960. Inimical effects on wildlife of periodic DDD applications to Clear Lake, Calif. Calif. Fish and Game 46 (1):91–106.

JOHNSON, B. T., R. N. GOODMAN AND H. S. GOLDBURG
1967. Conversion of DDT to DDD by pathogenic and saprophytic bacteria associated with plants. Science 157:560–561.

KLEINERT, S. J., P. E. DEGURSE, T. L. WIRTH AND L. C. HALL
1967. DDT and dieldrin residues found in Wisconsin fishes from the survey of 1966. Wis. Conserv. Dept. Research & Planning Div., Research Rept. No. 23 (Fisheries), 29 p.

KLEINERT, S. J. AND P. E. DEGURSE
1968. Survival of walleye eggs and fry of known DDT residue levels from ten Wisconsin waters in 1967. Dept. of Natural Resources Bureau of Research, Research Rept. (in press).

KURTZ, A. R., D. N. MCDOWELL, R. L. NORGREN, AND J. R. REYNOLDS
1967. 1967 Dutch Elm disease report. Wisconsin Department of Agriculture, Madison, Wisconsin, 15 p.

LICHTENSTEIN, E. P. AND K. R. SCHULZ
1959. Persistence of some chlorinated hydrocarbon insecticides as influenced by soil types, temperature, and rate of application. J. Econ. Entomol., 52:124.
1960. Translocation of insecticides into the aerial parts of peas under greenhouse conditions. J. Agr. Food Chem., 8:452.
1965. Residues of aldrin and heptachlor in soils and their translocation into various crops. J. Agr. Food Chem. 13:57.

LICHTENSTEIN, E. P., G. R. MYRDAL, AND K. R. SCHULZ
1965. Absorption of insecticidal residues from contaminated soils into five carrot varieties. J. Agr. Food Chem., 13:126.

MCKEE, J. R. AND H. W. WOLF
1963. Water quality criteria. State Water Quality Control Board, Sacramento, California. Publ. No. 3-A, 548 p.

MOUBRY, R. J., J. M. HELM AND G. R. MYRDAL
1968. Chlorinated hydrocarbon residues in an aquatic environment located adjacent to a commercial orchard. Pesticides Monitoring J. 1(4):27–29.

PREMDAS, F. H. AND J. M. ANDERSON
1963. The uptake and detoxification of C14-labelled DDT in Atlantic salmon, *Salmo salar*. J. Fish Res. Bd. Canada, 20(3):827–837.

PRESIDENT'S SCIENCE ADVISORY COMMITTEE
1963a. Use of pesticides. Washington, D.C. 25 p.
1963b. Restoring the quality of our environment. Rept. of Environment Pollution Panel. Washington, D.C., 317 p.

REINERT, R. E.
1968. The effect of dressing, filleting, and cooking on the reduction of pesticide levels in chub and perch. Univ. of Wis.–Milwaukee, Center for Great Lakes Studies, Special Rept. No. 3, pp. 8–9.

STATE OF WISCONSIN
1961. Report of the subcommittee on relation of chemicals to forestry and wildlife for the state of Wisconsin. Governor's Special Committee on Chemicals and Health Hazards. Madison, Wis.

TARRANT, R. F.
1966. Pesticides in forest water—symptom of a growing problem. Proc. Soc. Amer. Foresters, 1966:159–163.

TARZWELL, C. M.
1965. The toxicity of synthetic pesticides to aquatic organisms and suggestions for meeting the problem. *In:* Ecology and the Industrial Society, 5th Symposium Brit. Ecol. Soc. Blackwell Sci. Publ., Oxford, pp. 197–218.

THE PESTICIDE REVIEW
1966. Agric. Stab. and Conserv. Serv., U. S. Dept. of Agriculture, Washington, D.C.

THOMPSON, D. R.
1966. Pesticide residues in Wisconsin fish. Wis. Conserv. Dept., Research & Planning Div., Madison, Wis. Survey Rept. 8 p.

TOMPKINS, W. A., J. A. MCCANN, L. D. LYMAN AND N. B. GIBREE
1967. Massachusetts pesticide monitoring study. Div. of Fisheries and Game, Westboro, Mass. Progress Rept. No. 2, 19 p.

UNITED STATES BUREAU OF THE CENSUS
1964. U. S. Census of Agriculture, Vol. I. Part 14.

UNITED STATES DEPARTMENT OF AGRICULTURE
1966. Lawn insects; how to control them. U. S. Dept. Agric. Home and Garden Bull. 53, 24 p.
1967. Insects and diseases of vegetables in the home garden. U. S. Dept. Agric. Home and Garden Bull. 46, 50 p.

UNITED STATES DEPARTMENT OF HEALTH, EDUCATION AND WELFARE
1965. Pesticide analytical manual, Vol. I. Food and Drug Admins., Washington, D.C. Rev. 1965.

WALTERS, H. M., C. W. LEGRANDE, J. B. GOODWIN, L. E. KRAHN AND R. J. RIES
1967. Wisconsin agricultural statistics 1967. Wisconsin Dept. of Agriculture, Madison, Wisconsin. 85 p.

WARNER, RICHARD E., KAREN K. PETERSON AND L. BORGMAN
1966. Behavioral pathology in fish: a quantitative study of sublethal pesticide toxication. *In:* Pesticides in the environment and their effects on wildlife. J. Appl. Ecol. 3:223–247 (Suppl.).

WEAVER, L., C. G. GUNNERSON, A. W. BREIDENBAC AND J. J. LICHTENBERG
1965. Chlorinated hydrocarbon pesticides in major U. S. river basins. Pub. Health Rept. 80(6):481–493.

WOODWELL, G. M.
1967. Toxic substances and ecological cycles. Sci. Amer., 216(3):24–31.

WOODWELL, G. M., C. F. WURSTER, JR., AND P. A. ISAACSON
1967. DDT residues in an east coast estuary: a case of biological concentration of a persistent insecticide. Science, 156:821–824.

WISCONSIN AGRICULTURAL EXTENSION SERVICE
1968a. Insect control. Spec. Circ. 113, 24 p.
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