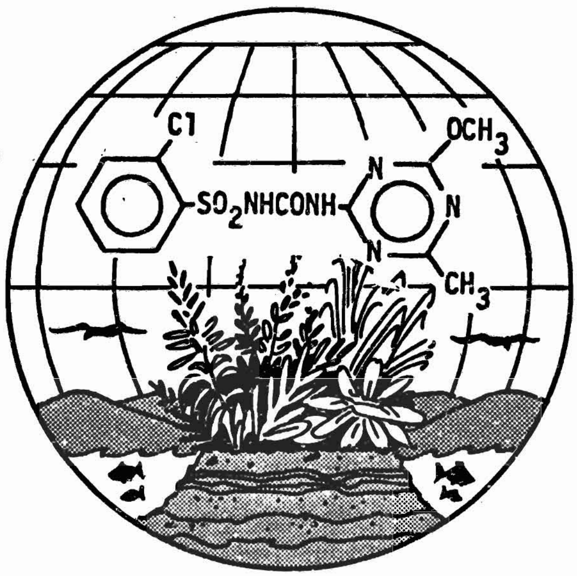
Overview of Pesticide Effects and Pesticide Application in Virginia Agriculture



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"They came in swarms and settled over the whole country. They covered the ground until it was black with them; they ate everything including all the fruits on the trees. Not a green thing was left on any tree or plant in all the land of Egypt..." (Exodus 10: 14-15). The Old Testament describes the struggle between humans and pests as harsh from the beginning, and catastrophic from time to time, causing large-scale famines.

Many centuries ago, sophisticated agricultural societies used some type of chemicals for pest control. For example, sulphur was used for disease and insect control before 1000 B.C., and the use of arsenic for insect control was advocated about 79 A.D.[1] However, the era of those modern synthetic organic chemicals known as pesticides began in the 1930's and was greatly advanced in the 1940's during and after World War II. The beginning of this era was symbolized by the use of the insecticide DDT, a great success story. By 1972, the lives of 1.5 billion people were improved by the eradication of malaria in 37 countries and the reduction in the reported cases of malaria in 80 other countries.[2] The DDT success in exterminating the mosquitoes which served as vectors of malaria, prompted the formulation and widespread use of other insecticides and that of two other categories of pesticides, namely herbicides for weed control and fungicides for plant disease control.

These three major categories of pesticides have evolved at different rates. The chemistry of insecticidal products has developed through four generations: (1) organochlorines, such as DDT, chlordane, aldrin and dieldrin; (2) organophosphates, such as parathion; (3) carbamates, such as carbaryl and carbofuran; and (4) pyrethroids, such as permethrin and cypermethrin.

Chemical classes of herbicides include phenoxy herbicides, such as 2,4-D; triazines, such as atrazine and cyanazine; benzoic acids, such as dicamba; acetanilides, such as alachlor and metolachlor; and ureas, such as linuron. Several new classes of herbicides were registered in 1986. The two most important of these are the imidazolinones and the sulfonylureas. These herbicides are non-oncogenic and are effective at lower application rates than the conventional herbicides.

Fungicides registered in the 1950s and 1960s are still widely used. These early fungicides are relatively inexpensive, are effective against a broad range of plant pathogens, are less likely to stimulate pest resistance, and exhibit low acute toxicity. In addition, they are often important in integrated disease management programs. These fungicides include captafol, captan, chlorothalonil, folpet, mancozet, maneb, o-phenylphenol, PCNB, and zineb.

Today pesticides are used not only in agriculture but for many diverse purposes such as human and animal health protection, pest control in forest and aquatic environments, and protection of buildings and other structures. However, more than 70 percent of all pesticides used in the United States is applied to agricultural lands. In 1985, U.S. farmers applied about 400 million kg of pesticides to agricultural lands.[3]

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Increased and continued use of pesticides is associated with increased risks to human health, adverse effects on nontarget organisms, and contamination of air, soil, and water. Less than 0.1 percent of the applied pesticides are estimated to actually reach the targeted pests, and therefore large amounts are entering the environment and contaminating soil and water resources.[4] The objective of this article is to review the current state of knowledge about pesticides in environment, current management guidelines and methods, and future trends.

Fate of Pesticides in the Environment

Sources of pesticides in the environment include those resulting from the direct application of pesticides for a specific purpose such as pesticides used for weed and insect control in aquatic environments, and those entering indirectly from spray drift, atmospheric precipitation, runoff and erosion from agricultural lands, effluent discharges from sewers and factories, accidental spills, and volatilization. Once in the environment, a pesticide follows a pathway determined by the pesticide's characteristics and its encompassing environment. Water solubility, adsorption characteristics, half-life persistence, and volatility are major chemical characteristics determining the fate of a pesticide in the environment. The pesticide formulation and method of application are also important. For example, granular formulations are usually the most persistent; wettable powder and dust formulations are often less persistent than emulsifiable formulations. Application techniques, whether aerial, surface, or subsurface, introduce the pesticide into a different environmental compartment and result in a particular interaction with the environment.

Pesticides in Aquatic Environments

Aquatic environments are rivers, streams, lakes, reservoirs, marshes, estuaries, and oceanic waters. The quantity of a pesticide moving with runoff and sediment to an aquatic environment depends on a number of factors. These include topography, intensity and duration of rainfall or irrigation, soil erodibility, land management, and cropping practices. Persistence of the pesticide in soil, a variable factor depending on the soil environment, is an important element that affects movement of a pesticide to the aquatic environment. Picloram, for example, has been reported to effectively disappear from the soil in as short as 50 days or as long as 6 years, but its persistence under moderate conditions is generally about 1.5 years.[5]

Some of the important properties of aquatic environments that affect the magnitude of pollution include surface area and depth, hydraulic properties, and geographic location. Although severity of pesticide pollution in an aquatic system varies according to those factors, in general, the highest pesticide residues are observed in rivers, lower residues occur in estuaries, and the least is found in the oceans. The magnitude of pollution in lakes and reservoirs depends on their location in an agricultural or industrial setting.

When a pesticide enters an aquatic environment, it may volatilize, remain dissolved in the water, stay in suspension as microcrystals, adsorb onto particulate matter in the water, be deposited in the bottom sediments, or accumulate in living organisms. Therefore, in an aquatic system, residue from pesticides may occur in water, mud, sediment, plankton and suspended material, fish and other animals, and plants. The dynamics of pesticide interaction in an aquatic environment are quite complex and are influenced by a combination of physical, chemical and biological processes.

Physical processes include dilution and mixing of the pesticide's concentration in an aquatic environment. Dilution may be caused by the dispersion or diffusion of the pesticides in the water body, its transport with water currents or eroded bottom sediments, and its movement to the atmosphere through volatilization from the water surface. Also, large amounts of pesticides are transported or diluted physically by the migration of fish or drift of insects because these organisms accumulate and concentrate pesticides in their bodies.

Chemical processes within the aquatic environment include aqueous ionization, hydrolysis, chemical oxidation, and photolysis. The environmental behavior of some pesticides are substantially modified by ionization in aqueous solution and subsequent formation of bound residues. Hydrolysis reactions are a major factor in the environmental degradation of some pesticides. These are generally second-order reactions, with the reaction rate highly dependent upon pH. Oxidation reactions occur through the interaction of substances that have naturally occurring free radicals in water. Photolysis in an aquatic environment is a dominant degradative pathway for many pesticides. The rate at which a pesticide is photodegraded is a function of the properties of the chemical and of the environment.

Biological processes in an aquatic environment include microbial transformations and bioaccumulation. Some pesticides are biodegraded by the action of heterotrophic microorganisms ubiquitous to aquatic environments. Environmental conditions, such as dissolved oxygen concentration and temperature, influence the number of microorganisms and the rate of microbial degradation of pesticides in natural waters.

Many pesticides can accumulate in the tissues of aquatic animals and plants by direct uptake or bioconcentration. Bioaccumulation is associated with the accumulation of the chemical in the organism through adsorption, absorption, and ingestion. Environmental factors affecting bioaccumulation are temperature, dissolved oxygen concentration, and food availability. Organismic properties influencing bioaccumulation include size, surface area/volume ratio, lipid content, growth rate, and age. The properties of a pesticide affecting bioaccumulation include the pesticide's susceptibility to metabolic degradation and its relative affinity for lipids versus water, which is estimated by octanol/water partitioning. In general, organochlorine-type compounds, which are more hydrophobic, bioaccumulate more than other pesticides.

Several fish species such as rainbow trout and fathead minnows, and invertebrates such as rotifers and daphnids are used for bioaccumulation studies. Bioaccumulation is considered an important tool for water quality monitoring in aquatic environments. Data on pesticide residue in water tend to vary markedly with season, the degree of water turbulence, and the amount of suspended particulate matter. Fish are often considered a better indicator of pesticide pollution than water samples because the residues in fish tissues are several orders of magnitude higher and are much easier to analyze.

In general, highly water-soluble pesticides are more easily diluted and tend to be less persistent in water. By contrast, water insoluble pesticides are not readily leached into aquatic systems, but once there they are rapidly bound to living or dead organic matter or fractions of the bottom sediment. In terms of pesticide type, persistence in the total aquatic system is greatest for organochlorine insecticides, intermediate for organophosphate and carbamate insecticides, and least for herbicides. However, some soluble herbicides that reach surface water, such as atrazine, display a tendency to remain in solution for long periods. But most herbicides are less likely to bioconcentrate and are less toxic to fish.

Pesticide Movement to Groundwater

The movement of pesticides from the soil surface through the soil to the groundwater is a complex process. Factors which influence the movement of pesticides to groundwater include pesticide formulation, pesticide chemical properties and method of application, land forms (topography, slope length, drainage pattern) plant factors (type of crop, stage of growth, root system), and seasonal groundwater elevation. Pesticides move through the soil with infiltrating water, and the amount of pesticide transported from the soil into groundwater is governed by pesticide retention, transformation, and volatilization.

Retention refers to adsorption of pesticides within the soil system. Adsorption is a reversible process involving attraction of a chemical to the soil particle surface and the retention of this chemical for a certain period of time. The mechanism of pesticide adsorption is complex but its intensity is generally correlated to the soil mineral and organic matter content. The extent of adsorption of pesticides to soils is usually determined by the ratio of distribution of the chemical between the soil water and soil solid phase and is expressed as K_d.

Pesticide transformation refers to changes in the chemical structure or composition of a pesticide due to degradation within the soil system. The kinetics of pesticide degradation are affected by the pesticides properties and its availability in soil water, the presence of microorganisms or enzyme systems capable of degrading the pesticides, the activity level of the microorganisms as affected by available nutrients for microbial growth, and environmental conditions such as temperature, moisture, aeration, and various soil properties. Biodegradation is most significant in the root zone because of the higher concentration of organisms in residence, decreases below the root zone because of lower biological activity, and occurs at a much slower rate in the deeper unsaturated zone as well as in groundwater. However, anaerobic decomposition may take place in deep soils and aquifers under appropriate environmental conditions. Degradation potential or rate of dissipation of pesticides from a soil-water system is expressed as the pesticide's half-life, the time required for half of the chemical to dissipate from a particular system. Hydrolysis half-life is obtained under controlled conditions in the laboratory. Soil half-life which represents field conditions includes losses due to hydrolysis, microbial activity, volatilization and other factors. As discussed later, half-life values, K_d values, pesticide solubility and results from environmental fate studies are used by the U.S. Environmental Protection Agency (EPA) to determine leachability of pesticides to groundwater.

A pesticide's movement to groundwater is also influenced by its volatilization from the root zone. Volatilization is a function of the vapor pressure of the pesticide and is affected by pesticide concentration, soil-moisture content, soil adsorption characteristics, diffusion rate in soil, temperature, and air movement. The volatilization of pesticides from the soil occurs in two stages. The first stage is the upward movement of dissolved or soluble pesticide in water with evaporation from the lower soil profile. The second stage involves the escape of pesticides from the soil surface to the atmosphere.

A 1986 EPA report lists 17 different pesticides detected in the groundwaters of 23 states (Table 1). The concentrations of these pesticides in groundwater range from trace amounts to several hundred parts per billion. These detections of pesticides in groundwater can be attributed to advancements in monitoring and analytical techniques. Although widespread contamination of groundwater by pesticides has not been observed, the public is concerned about potential groundwater contamination from the increased use of pesticides during the past two decades. Widespread public concern has led to increased support from governmental agencies and industry for initiating and implementing groundwater monitoring programs and researching the fate of pesticides in the groundwater. Measures to prevent contamination include evaluation of applications to register new pesticides for their potential impact on groundwater and re-evaluation of licenses for continued use of older pesticides during reregistration or when changes to approved use are requested. Also, techniques such as DRASTIC have been developed to identify the relationship between pesticide application and groundwater vulnerability factors.[6]

Determining Pesticide Leachability to Groundwater

The EPA requires all pesticide registrants to submit a data package containing information on pesticide properties (solubility, K_d, vapor pressure, water-air ratio, and octanol-water partition coefficient) and the results of environmental fate studies performed according to EPA guidelines. In general, a complete package of environmental fate studies requires data on hydrolysis and photolysis; aerobic and anaerobic metabolism; leaching properties; field dissipation in soil, sediment, water, and forests; and accumulation in crops, and fish and other non-target aquatic organisms. The environmental fate data required to determine a pesticide's potential to reach groundwater include results on hydrolysis, photolysis in water and soil, aerobic and anaerobic metabolism in soil, aquatic metabolism, leaching, and field dissipation. A pesticide is categorized as having a potential to reach groundwater if, based on a review of the environmental studies, the pesticide meets at least one of the following criteria: \[7,8]

1) Water solubility greater than 30 ppm; 2) K_d <5; 3) hydrolysis half-life greater than about 25 weeks; or 4) soil half-life (field) greater than about 2 or 3 weeks. Designating a pesticide as a potential leacher, based on only one criterion may appear to be an overly conservative approach. However, Creeger[7] noted that EPA's criteria are based on extreme conditions. For example, a chemical is subjected to a heavy rainfall or irrigation soon after its application, causing its immediate leaching through the topsoil into the deeper soil layers, where it may persist and become available for further leaching into groundwater. Applying the above criteria, EPA has banned or restricted the use of several pesticides such as DBCP, EDB, oxamyl, and aldicarb.

Establishing Toxicity Effects

All pesticides are toxic and may adversely affect humans and other organisms. Their degree of harmfulness to humans and other living organisms depends on the pesticide characteristics, the amount or dosage of the pesticide, and the duration of exposure or contact time. Therefore, a major question to be answered in establishing toxicity effects of a pesticide is "what is the risk of receiving a particular dose of a pesticide over a given period of time?" These risk assessments are based on dose-response studies performed in the laboratory, natural ecosystems, and mesocosms (experimental pond and in situ enclosures). The economic benefits from the use of a pesticide should not outweigh its potentially negative health and ecological effects. Results of environmental fate studies required by the EPA for pesticide registration include results for toxicological tests. The two major categories of toxicological tests are 1) those that determine a pesticide's toxic effects on mammals such as rabbits, rats and dogs and these results are extrapolated to human beings, and 2) those toxic effects estimated for various aquatic organisms such as fish and invertebrates.

Toxicity tests on mammals provide a database that can be used to evaluate the hazards and assess the risks associated with the use of a pesticide. Major categories of mammalian toxicity studies include acute, chronic, and mutagenicity tests.

The purpose of acute toxicity tests is to establish the median lethal dose (LD_{50}), the dose required to kill 50% of the population of test animals. LD_{50} is expressed as mg/kg of the animal's body weight and is the most reproducible response that can be estimated with the highest statistical confidence. The smaller the LD_{50} value, the more toxic the chemical. For example, pesticides with LD_{50} values of 1 to 50 are highly toxic (dinoseb, aldicarb, carbofuran, demeton, phorate, endrin), and those with LD_{50} values of greater than 15,000 (ferbam) are considered relatively harmless (Table 2). The majority of pesticides are slightly to moderately toxic. Acute toxicity effects from ingestion, inhalation, and skin and eye contact are determined over a two to three week post-exposure observation period.

Chronic tests measure effects of long-term exposure to a pesticide. The EPA requires that the highest dose tested in these studies must be the maximum tolerated dose (MTD) or one that produces some toxic or pharmacological effect in the experimental animals. A lower dose level which produces no evidence of toxicity also must be used. This is called the "no observed effect level" or the NOEL.[9] In practice, NOEL determined from chronic studies of the most sensitive species is used as a criterion. A safety factor of 100 is commonly used to extrapolate animal test results to a safe dose for human consumption. However, carcinogenic and mutagenic pesticides have no threshold dose or applicable safety factor. In these cases, mathematical models are used to estimate risks and the probability of tumor occurrence in humans.[9]

The biological response of aquatic organisms to a chemical concentration is expressed as the median level concentration, LC_{50}, the estimated concentration in water (mg/l) which will kill or immobilize 50% of the test organisms in a predetermined length of time. The LC_{50} is expressed as the length of time required to produce the desired response, for example, 96-hr LC_{50}. Smaller LC_{50} values indicate higher toxicity. The LC_{50} value for DDT, endrin, and paraquat are 0.002, 0.0002, and 400 mg/l, respectively (Table 2). Usually rainbow trout or bluegill sunfish in static water tests are used as standard indices of fish toxicity. Other fish species used in acute toxicity tests include goldfish, killifish, spot, mullet, harlequin fish, catfish, and fathead minnows.

Three categories of toxicity tests are commonly used to predict the chronic effects of toxic chemicals on aquatic organisms.[10] \Life-cycle toxicity tests measure the effects of chronic chemical exposure on reproduction, growth, survival, and other variables over one or more generations of organisms. The effects of chronic chemical exposure on the survival and growth of the toxicologically most sensitive life stages of a species, such as, the eggs and larvae of fishes, represent the second category of toxicity test. Functional tests, the third category, measure the effects of chemicals on various physiological functions of individual aquatic organisms. The data from all three categories of tests are used to estimate chronic toxicity threshold concentrations (Table 3).

Pesticide Regulations

Federal regulation of pesticides began with the Federal Insecticide Act of 1910. However, the act was only concerned with offenses such as adulterating a product and not with safety of pesticides. In 1947, Congress approved the first version of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). This act authorized the U.S. Department of Agriculture (USDA) to enforce all pesticide regulations, but again the act only protected consumers from ineffective products. In 1970, jurisdiction of the FIFRA was passed from USDA to the newly formed EPA. In 1972, FIFRA was amended to change its focus from efficacy to safety. The Federal Environmental Pesticide Control Act of 1972, PL 91-516, provided the format for current pesticide regulations and is still referred to as FIFRA. The 1972 amendments introduced the concept of risk evaluation and required EPA to consider environmental risks before registering a product. According to the amendments, EPA must re-examine, or reregister products approved for registration before 1972. Pesticides that fail to meet EPA's standards or that pose unreasonable adverse effects are denied registration or cancelled. FIFRA requires EPA to consider not only the risks posed by a pesticide, but also, economic, social, health, and environmental benefits. The most recent amendments of 1978 addressed EPA's problems with reregistering old pesticides. These amendments allowed EPA to group the pesticides by active ingredients and register them on a generic, rather than individual product basis.

FIFRA Reauthorization Bill

Each year since 1980, Congress has considered legislation to revise the federal regulatory program for pesticides. The reauthorization bill would give EPA the legislative mandate and funding to accelerate and complete the reregistration of about 600 pesticide active ingredients in 10 years rather than 30. Other relatively non-controversial sections of the legislation would increase the penalties for violating FIFRA (the present maximum is $5,000); allow more public access to EPA information on pesticides provided by registrants; and give the agency greater enforcement power.[11] However, acceptable sources of funding for the implementation of reregistration program and reimbursements for cancelled pesticides are major obstacles to pass the reauthorization bill.

A number of interest groups have joined the reauthorization bill debate, complicating the situation. The agricultural chemical industry, environmental organizations, labor unions, consumer groups, the farm bureau, and smaller pesticide manufacturers are lobbying Congress to protect their diverse positions and interests. Any compromise leading to the passage of the reauthorization bill will most probably not occur until after the 1988 elections.

Regulations for Pesticide Waste Disposal

Wastes containing pesticides originate from several sources: the manufacturing, testing, and formulation of pesticides; the empty containers; wastewater from rinsing commercial aerial applicators; and old and cancelled pesticides which must be disposed of. Numerous disposal and treatment technologies are applied to pesticide wastes. These include land disposal, incineration, open burning, physical/chemical treatment, and biological treatment. The application of these methods to pesticide wastes is regulated by the provisions of FIFRA and the Resource Conservation and Recovery Act (RCRA) of 1976.

The FIFRA amendments of 1972, Section 19 state that, "The administrator shall establish procedures and regulations for disposal or storage of packages and containers of pesticides, and accept at convenient locations for safe disposal, a pesticide the registration of which is cancelled under Section 6(c) if requested by the owner of the pesticide." Another section of FIFRA that concerns pesticide waste disposal is the labeling requirement (40 CFR 162.10). Section 12(a)(2)(g) of FIFRA states that it is unlawful to use any pesticide in a manner inconsistent with its labeling, and disposal has been determined to be part of the use process.

Pesticide wastes are partially regulated under the provisions of RCRA if they are identified as hazardous wastes. Pesticide wastes are considered hazardous if they are solvent based and have a flash point of $< 60°C$; are aqueous and have a pH of <2.0 or >12.5; or release HCN or H_2S upon contact with acids. In fact, toxicity characteristics of hazardous wastes defined by RCRA (referred to as extraction procedures or EP toxicity) are based on threshold concentrations of six pesticides (2,4-D, endrin, lindane, methoxychlor, silvex, toxaphene) and eight metals. Sixteen of the specific hazardous waste streams listed by EPA result from the manufacture of nine pesticides (cacodylic acid, chlordane, creosote, 2,4-D, disulfoton, MSMA, phorate, 2,4,5-T, toxaphene). About one-fifth of the 375 substances listed as hazardous chemicals are pesticide active ingredients.[12] The RCRA regulations also provide standards for construction and operation of certain disposal facilities. All facilities engaged in the treatment, storage, or disposal of hazardous pesticides, must be permitted by either EPA or an authorized state agency (40 CFR 264, 165).

Future Directions and Needs

Since publication of "Silent Spring" in the early '70's, much attention has been focused on the fate of pesticides in the environment. Elaborate monitoring and research programs are initiated by state and federal agencies and industry to study the fate of pesticides in surface and groundwaters. Regulatory requirements for pesticide registration and disposal are more stringent than two decades ago. While FIFRA and RCRA discussed in this paper are the two major laws regulating pesticides, the Clean Water Act Amendments of 1978 and 1987 were passed to control nonpoint source pollution and reduce pesticide input from agricultural fields to water bodies. The Toxic Substances Control Act (TSCA) authorizes the EPA and the states to restrict the use of certain pesticides in particular geographic areas to protect water from contamination. The Safe Drinking Water Act and subsequent amendments of 1986 have established standards for certain pesticide concentrations in drinking water. Recently, EPA proposed a pesticide strategy directing efforts toward preventing unacceptable contamination of current and potential drinking water supplies.[13] In the proposed strategy, the EPA is using Maximum Contaminant Levels (MCLs), the enforceable drinking water standards under the Safe Drinking Water Act, as reference points to determine unacceptable levels of pesticides in underground sources of drinking water. If an MCL for a particular pesticide is not yet available, EPA will develop interim protection criteria for use as reference values in pesticide management decisions. These interim references will be based on EPA's standard toxicological assessment procedures. For pesticides that have a carcinogenic potential, the interim reference value will be the concentration determined to pose a negligible risk.

The EPA's definition of a negligible risk for a carcinogen is the pesticide concentration in drinking water that poses a one in a million (10^{-6}) increased chance of cancer occurrence should an individual drink that water (1.0 liter per day by a 10-Kg child or 2.0 liters by a 70-Kg adult) over a life time (70 years).

Two other laws affect pesticide management. The Endangered Species Act of 1973 restricts the use of some pesticides on lands near the range of endangered species, and the Federal Food, Drug and Cosmetic Act (FFDCA) regulates pesticide residues in human food and animal feed.

Despite the regulations, many problems remain to be solved in the 1990's and during the next century. One major problem is the lack of a comprehensive database on pesticide use that could be used for risk assessment studies. A recent survey by Resources For the Future (RFF)[14] reported that nine states, including some major agricultural states, have absolutely no records of pesticide use. Nine other states have published reports on pesticide use and application to agricultural crops but their data have not been updated regularly. According to the RFF report, only the states of Hawaii, Oregon, Ohio, and New Hampshire produce regular up-to-date reports. All other remaining states have incomplete pesticide use reports.

Despite some progress, the reregistration of old pesticides is behind schedule and of the 600 individual active ingredients under review, only a few have been cancelled voluntarily or have been suspended by EPA. The FIFRA reauthorization bill aimed at accelerating the reregistration process, is blocked by lobbying of interest groups and is not expected to become law in the near future.

Meanwhile, over one million kg of pesticides are introduced each day into agricultural environments of the United States. Specialized monoculture farming systems have caused target organisms to become resistant to pesticides. Increased populations of "secondary pests" have resulted in development and use of more new pesticides to combat the situation. In 1984, 447 species of insects and mites, 100 species of plant pathogens, 55 species of weeds, 2 species of nematodes, and 5 species of rodents were known to be resistant in some location to one or more pesticides used for their control.[15]

In spite of advances in risk assessment, the chronic health effects of pesticide use are still uncertain. Because of advances in biotechnology, the new generation of pesticides may prove to be less toxic, non-oncogenic, and less persistent in the environment. However, older generations of pesticides will tend to remain in the environment and their total impact will be known only with the passage of time.

The development of alternative and innovative technologies to shift complete reliance from pesticides to other methods of pest control is one answer to the continued dilemma of pesticide pollution. For example, Integrated Pest Management (IPM) combines various nonchemical techniques with judicious chemical applications. Advances in genetic engineering, biological control, and plant breeding also may result in ultimately reducing the use of farm chemicals. However, at present, legal and regulatory issues have significantly slowed development and testing of genetically engineered biological control agents. Intensive research and education programs, and funds to support such programs are needed for new technologies to become available and consequently result in reduced and/or environmentally safe pesticide use.

Table 1. Typical Positive Results of Pesticide Groundwater Monitoring in the U.S.+ (Cohen, et al. 1986)

Pesticide	Use*	State(s)	Typical Positive ppb
Alachlor	H	Md, IA, NE, PA	0.1-10
Aldicarb (sulfoxide) & sulfone)	I,N	AR, AZ, CA, FL, MA, ME, NC, NJ, NY, OR, RI, TX, VA, WA, WI	1-50
Atrazine	H	PA, IA, NE, WI, MD	0.3-3
Bromacil	H	FL	300
Carbofuran	I,N	NY, WI, MD	1-50
Cyanazine	H	IA, PA	0.1-1.0
DBCP	N	AZ, CA, HI, MD, SC	0.02-20
DCPA (and acid products)	H	NY	50-700
1,2-Dichloro-propane	N	CA, MD, NY, WA	1-50
Dinoseb	H	NY	1-5
Dyfonate	I	IA	0.1
EDB	N	CA, FL, GA, SC, WA, AZ, MA, CT	0.05-20
Metolachlor	H	IA, PA	0.1-0.4
Metribuzin	H	IA	1.0-4.3
Oxamyl	I,N	NY, RI	5-65
Simazine	H	CA, PA, MD	0.2-3.0
1,2,3-Trichlor-opropane	N (impurity)	CA, HI	0.1-5.0

+Total of 17 different pesticides in a total of 23 different states.

*H = herbicide
I = insecticide
N = nematicide

This EPA finding is from a 1984 survey and shows 17 pesticides in groundwaters of 23 states as a result of normal agricultural practices. An update has not been published at this time. However, according to the USEPA Office of the National Pesticide Survey probably as many as 50 pesticides are detected in groundwaters of 30 states (personal communication, National Pesticide Survey).

Table 2. Toxicities of Pesticides

Common Name	Type of Pesticide	TOXICITY Rat, Acute Oral LD_{50} Mg/Kg	Fish[1] LC_{50} Mg/l
Alachlor	H	1200	2.3
Atrazine	H	3080	12.6
Benefin	H	800	0.03
Bromacil	H	5200	70
Butylate	H	4500	4.2
Chloramben	H	3500	7.0
Cyanazine	H	334	4.9
2,4-D Acid	H	370	>50[4]
2,4-D Amine	H	370	>15[3]
Dalapon	H	6590	>100
Dicamba	H	1028	35
Dinoseb	H	5	0.4[2]
Diquat	H	400	12.3
Diuron	H	3400	>60
Fenuron	H	6400	53
Linuron	H	1500	16.0
Metribuzin	H	1930	>100
Paraquat	H	150	400
Picloram	H	8200	2.5
Prometone	H	1750	>1.0[4]
Propachler	H	710	1.3
Propazine	H	5000	>100
Simazine	H	500	5.0
2,4,5-T	H	300	0.5-16.7
Trifluralin	H	3700	0.1
Aldicarb	I,N	0.93	-
Aldrin	I	35	0.019
Azinphosmythyl	I	11	0.010
Carbaryl	I	500	1.0
Carbofuron	I,N	8	0.21
Chlordane	I	335	0.010
Chlorpyrifos	I	97	0.020
DDT	I	113	0.002
Demeton	I,N	2	0.081
Diazinon	I,N	76	0.030
Dicofol	I	684	0.10
Dieldrin	I	46	0.003
Disulfston	I	2	0.040
Endosulfon	I	18	0.001
Endrin	I	7.3	0.0002
Ethion	I	27	0.23
Fonofos	I	8	0.03
Heptachlor	I	90	0.009
Malathion	I	480	0.019
Methyl Parathion	I	9	1.9
Monocrotophus	I	21	7.0
Parathion	I	4	0.047
Phorate	I,N	1	0.0055
Phosalone	I	96	3.4

Table 2. Toxicities of Pesticides - Continued

Common Name	Type of Pesticide	TOXICITY: Rat, Acute Oral LD_{50} Mg/Kg	TOXICITY: Fish[1] LC_{50}Mg/l
Phosmet	I	147	0.03[4]
Toxaphene	I	69	0.003
Benomyl	F	>9590	0.5
Captafol	F	500	0.031
Captan	F	9000	0.13
Carboxin	F	3200	2.2
Dinocap	F	980	0.14
Dodine	F	1000	0.9
Ferbam	F	>17000	12.6
Maneb	F	6750	1.0
Metiram	F	6400	>4.2
Thiram	F	375	0.79
Zieneb	F	>5200	0.5
Ziram	F	1400	1.0

- H; Herbicide
- I; Insecticide
- N; Nematicide
- F; Fungicide

[1]48 or 96-hour LC_{50} for bluegills or rainbow trout, unless otherwise specified.
[2]LC_{100} for goldfish
[3]For spot
[4]For Killifish

Source: Control of Water Pollution from Cropland: EPA-600/2-75-026a

Table 3. EPA Toxicology Data Requirements (Cardona, 1987)

Test	Exposure Duration	Species
Acute		
• Oral/Dermal/Inhalation	2 to 3 weeks	Rat, Rabbit
• Primary Eye/Dermal Irritation		Rabbit
• Dermal Sensitization		Guinea Pig
• Delayed Neurotoxicity[1]		Hen
Subchronic		
• 90 Day Feeding		90 days Rat and Dog
• 90 Dermal/Inhalation		Rat
• 90 Day Neurotoxicity[1]		Hen
Chronic		
• Ocogenicity[2]	2 yrs (rats); 18 mos. (mice)	Rat and Mouse
• Chronic Feeding	2 yrs (rats); 1 yr (dogs)	Rat and Dog
• Teratogenicity[3]		
Gestation (organic development)	6 to 15 days (rats) 6 to 18 days (rabbits)	Rat and Rabbit
Parturition (process of giving birth)	21 days (rats) 32 days (rabbits)	
• Reproduction, 2-Generation		Rat
Mutagenicity[4]		
• Gene Mutation		
• Chromosome Aberration		
• DNA Damage and Repair		
Special Tests		
• Metabolism[5]		Rat
• Dermal Penetration[6]		Rat

[1]Neurotoxicity test is required only if the pesticide is used on food and is an organophosphate.

[2]This test assesses the potential of the test agent to produce malignant and benign tumors.

[3]This test evaluates the potential fetotoxicity or birth defects in offspring.

[4]This test determines if the pesticide affects genetic components in the nucleus of the mammalian cell. These assays are also used to screen for potential carcinogens.

[5]This test determines the transformation, absorption, and distribution of pesticides in rats and excretion from rats.

[6]This test is needed for pesticides with serious toxic effects.

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Pesticide Use in Virginia

Purpose of Pesticide Use

In the State of Virginia, pesticides are used or recommended for the following purposes (Ref. Virginia Pesticide Law): 1) Agricultural pest control which includes pesticides used on agricultural crops and domestic animals; 2) forest pest control; 3) ornamental and turf pest control; 4) seed treatment; 5) aquatic pest control; 6) right-of-way pest control for highways and waterways; 7) public health pest control; 8) regulatory pest control such as pesticides used for quarantine and emergency measures; 9) demonstration and research pest control; and 10) industrial, institutional, structural, and health related pest controls (including general pest control in households, churches, offices, warehouses, schools, and factories for the protection of people, clothing, fabrics, paper, pets, and stored foods in private residences; control of wood-infesting organisms including termites, wood-destroying beetles and ants, fungal control for the preservation and protection of fences, materials, utility poles, buildings and other structures; food processing pest control in food manufacturing and processing plants and warehouses, food handling establishments, canneries, mills, dairies, restaurants, grain elevators, bakeries, ships, vehicles, meat packing plants, cafeterias, rest homes, and hospital food preparation areas).

Pest Management Guides for Virginia (Virginia Extension Service - 1986/1987) lists 111 herbicides, 107 insecticides, and 50 fungicides recommended for use in Virginia. These include pesticides used for corn, sorghum, soybeans, tobacco, peanuts, trees, and small fruits, home vegetable gardens, forests, Christmas trees, aquatic and non-crop areas, recreation and household areas, nursery ornamentals, floral crops, turfgrass, home fruit production, home ornamental plants, and insecticides for livestock pest management.

Pesticide Use Records and Amounts

Virginia is one of the few states which does not record statewide pesticide use. Therefore, the actual amounts of pesticides used in Virginia are unknown. However, Resources for the Future (RFF, 1986, 1987) recently prepared a national database which included estimates of pesticide use in Virginia agriculture. According to RFF's estimations, agricultural lands in Virginia receive about 5,001,991 pounds of active pesticide ingredients per year. RFF's information was extrapolated from known information of pesticide use for similar crops in adjacent states and assumed uniform pesticide application patterns throughout the states. Following the national trend, if agricultural pesticide use in Virginia corresponds to 70% of total pesticide use, then the total pesticide use in Virginia will amount to 6,502,588 pounds of active pesticide ingredients per year.

Pesticide Use in Virginia Agriculture

About 65 percent of the more than 5 million pounds of active pesticide ingredients (RFF 1986, 1987) applied to Virginia's farmlands are applied to agricultural fields within the Chesapeake Bay watershed. Thirteen counties in Virginia receive more than 100,000 pounds per year.

These counties are as follows:

County	Pesticide Application lbs/yr. Active Ingredient
Southampton	351,120
Isle of Wight	194,048
Suffolk	176,300
Rockingham	172,606
Loudon	154,259
Sussex	149,803
Frederick	141,698
Accomack	126,905
Greenville	117,941
Fauquier	112,369
Augusta	108,345
Essex	107,022
Pittsylvania	103,922

Seven counties in Virginia apply between 1,000 to 5,000 pounds of pesticides per year on agricultural land. These counties are Alleghany, Bath, Giles, Highland, Warren, Wise, and York. Two counties, namely Buchanan and Dickenson, received the lowest amount of pesticides on their agricultural land (< 1,000 lbs/yr).

According to Pest Management Guides for Virginia (Virginia Extension Service - 1986/1987) a total of 46 herbicides, 39 insecticides, and 22 fungicides are used or recommended for use on major crops in Virginia. These major crops include corn, sorghum, soybeans, peanuts, tobacco, trees and small fruits. Various pesticides used in Virginia agriculture according to crop needs are summarized below. Common names are followed by trade names in parentheses.

Crops	Types of Pesticide
Corn and Sorghum	<u>Herbicides:</u> Alachlor (Lasso), Ametryn (Evik)*, Atrazine (AAtrex), Bentazon (Basargan)*, Bromoxynil (Brominal), Butylate (Sutan)*, Chloramben (Amiben)*, Cyanazine (Bladex)*, Dicamba (Banvel), EPTC (Eptam)*, Eradicane*, Glyophosate (Roundup), Linuron (Lorox), Metalachlor (Dual), Paraquat (Gramoxone), Pendimethalin (Prowl)*, Propachlor (Ramord)**,Propazine (Milograd)**, Simazine (Princep)*, Sodiumchlorate (Atlacide)**, 2,4-D (Decamine). * Corn only **Sorghum only <u>Insecticides:</u> Carbaryl (Sevin), Carbufuren (Furadan), Carbophenothion (Trithion), Chlorpyrifes (Brodan), Diazinon (Spectracide), Dimethoate (Cygon), Disulfotan (Di-Syston), Ethion (Fosmite), Ethoprop (Mocap), Fensulfothion (Dasanit), Fenvalernate (Pydrin), Fonofos (Dyfonate), Malathion (Cythion), Methiocarb (Mesurol), Methomhyl (Lannate), Methyl Parathion (Penncap-M), Permethrin (Ambush), Phorate (Thimet), Terbufos (Counter), Toxaphene (Attac), Trichlorofon (Dylax). <u>Fungicides:</u> Captan (Orthocide), Carboxin (Vitavax), Thiram (Arasan).
Soybeans	<u>Herbicides:</u> Alachlor (Lasso), Acifluorfen (Blazer), Chloramben (Amiben), Dinoseb (Premerge), Dyanap (Ancrack), Fluchloralin (Basaline), Linuron (Lorox), Metholachlor (Dual), Metribuzin (Lexone), Oryzalin (Surflan), Pendimethalin (Prowl), Tribluralin (Treflan), Vernolate (Vernam). <u>Insecticides:</u> Acephate (Orthene), Aldicarb (Temik), Azinphos-Methyl (Guthion), Carbarly (Sevin), Carbophenothion (Trithion), Chlorpyrifos (Brodan), Dimethoate (Cygon), Disulfoton (Di-Syston), Fenvalerate (Pydrin), Methomyl (Lannate), Methyl Parathion (Penncap-M), Permethrin (Ambush), Phorate (Thimet). <u>Fungicides:</u> Benomyl (Benlate), Carbaxin (Vitavax), Chlorothalonil (Bravo), Metalaxyl (Apron), PCNB (Folosan), Thiophanate (Topsin M).

Crops	Types of Pesticide
Peanuts	<u>Herbicides:</u> Alachlor (Lasso), Acifluorfen (Blazen), Benefin (Balan), Bentazon (Basagran), Chloramben (Amiben), Dinoseb (Premerge), Diphenamid (Enide), Dyanap (Ancrack), Fluchloralin (Basalin), Metolachlor (Dual), Naptalam (Alanap), Pendimethalin (Prowl), Vernolate (Vernam), 2,4-DB (Butoxone). <u>Insecticides:</u> Acephate (Orthene), Aldicarb (Temik), Carbaryl (Sevin), Carbufuren (Furadan), Chlorphyrifos (Brodan), Disulfoton (Di-Syston), Ethoprop (Mocap), Fenvalevate (Pydrin), Fonofos (Dyfonate), Malathion (Cythion), Methomyl (Lannate), Monocrotophos (Azodrin), Phorate (Thimet), Propargite (Comite). <u>Fungicides:</u> Benomyl (Benlate), Captan (Orthocide), Captafol (Difolatan), Carboxin (Vitavax), Chlorothalonil (Bravo), Dichloran (DCNA), Maneb (Dithane M-22), Mancozeb (Manzate), PCNB (Floson), Thiophanate (Topsin M), Thiram (AAtack).
Tobacco	<u>Herbicides:</u> Benefin (Balan), Dipehnamid (Enide), Isopropalin (Paarlan), Napropamide (Devrinol), Orzalin (Surflan), Pebulate (Tillam), Pendimethalin (Prowl). <u>Insecticides:</u> Acephate (Orthene), Aldicarb (Temik), Azinphos-Methyl (Guthion), Bacillus Thuringiensis (Bactur), Carbaryl (Sevin), Carbufuren (Furadan), Diazinon (Spectracide), Disulfoton (Di-Syston), Endosulfan (Thiodan), Ethoprop (Mocap), Fensulfothion (Dasanit), Fonofos (Dyfonate), Malathion (Cythion), Metaldehyde (Metason), Methidathion (Supracide), Methomyl (Lannate), Methyl Parathion (Penncep-M), Monocrotophos (Azodrin), Oxamyl (Vydate), Trichlorfon (Dylox). <u>Fungicides:</u> Ferbam (Carbamate), Maneb (Dithane M-22), Metalaxyl (Apron).
Pastures	<u>Herbicides:</u> Dicamba (Banvel), Picloram (Tordan), 2,4-D (Decamine).

Crops	Types of Pesticide
Trees & Small Fruits	Herbicides: AMS (Ammate), Dalapon (Dowpon), Dichlobenil (Casoron), Diuran (Karmex), Flauzifop-butyl (Fusilade), Glyphosate (Roundup), Napropamide (Devrinol), Norflurazon (Zorial), Dryzalin (Surflan), Pronamide (Kerb), Sethoxydim (Poast), Simizane (Princep), Terbacil (Sinbar), 2-4D (Decamine). Insecticides: Azinphos-Methyl (Guthion), Chlorphyrifos (Brodan), Cyhexatin (Plictran), Demeton (Systox), Diazinon (Spectracide), Dicofol (Kelthane), Dimethoate (Cygon), Endosulfan (Thiodan), Formetanate (Carzol), Methidathion (Supracide), Methomyl (Lannate), Parathion (Bladan), Phosalone (Zolone), Phosmet (Imidan), Phosphamidon (Dimecron), Propargite (Comite). Fungicides: Benomyl (Benlate), Captan (Orthocide), Dikar, Dinocap (Karathan), Dodine (Cyprex), Ferbam (Carbamate), Folpet (Phaltan), Maneb (Dithane M-22), Mancozeb (Manzate), Metiram (Polyram), Thiophanate (Topsin M), Thiram (Arasan), Triadimefon (Bayleton), Triforin (Funginex), Zineb (Dithane Z-78).

Pesticides and Potential Water Pollution In Virginia

Herbicides, insecticides, and fungicides commonly used on Virginia croplands and properties of these pesticides that relate to water pollution and health hazards are provided in Table 4, 5 and 6.

Key to Tables

*	production discontinued
**	*restricted pesticide*
+	*leachers - there is a high probability that these pesticides will leach to groundwater according to the criteria established by EPA*

Sed.	*Denotes those pesticides that will most likely move primarily with sediment.*
Wat.	*denotes those pesticides that will most likely move primarily with water.*
Sed. Wat.	*denotes those pesticides that will most likely move in appreciable proportion with both sediment and water.*
U.	*The transport mode is unknown.*

(A) *arcaricide*
(N) *nematicide*

Sources of Information documented In Tables 4, 5 and 6.

1. Farm Chemical Handbook '87. Meister Pub. Co., OH.
2. Pest Management Guides for Virginia - 1986/87. Virginia Cooperative Extension Service Publ 456-001.
3. Control of Water Pollution from Cropland. Vol. 1, EPA-600/12-75-026a, Washington, DC.
4. The Magnitude and Cost of Groundwater Contamination from Agricultural Chemicals. USDA-AER, Report No. 576, 1987.

Table 4. Herbicides and Water Pollution Potential

Common Name	Trade Name	Predominant Transport Mode	Toxicity LD_{50} (mg/kg)	Toxicity LC_{50} (mg/l)	Approximate Persistance in Soil (days)	Crop Use
Alachlor+	Lasso	Sed. Wat.	1200-1800	2.3	40-70	Corn Soybeans Peanuts Sorghum
Acifluorfen+	Blazer	Sed. Wat	1300	U	U	Peanuts Soybeans
Ametryn+	Evik	Sed. Wat	1750	low tox.	30-90	Corn Potatoes
AMS	Ammonium, Sulfonate, Ammate	Wat.	3900	U	U	Trees Small Fruits
Atrazine+	AAtrex	Sed. Wat.	1780	12.6	300-500	Corn Sorghum
Benefin	Balan, Benfluralin	Sed.	>10000	0.03	120-150	Peanuts Tobacco
Bentazon+	Basagran	Wat.	1100-2063	190	U	Corn Peanuts
Bromoxynil	Brominal, Buctril, Brittox	Sed. Wat	260	0.05	U	Corn Sorghum
Butylate+	Suton, Genate plus	Sed.	3500-5431	4.2	40-80	Corn
Chloramben+	Amiben	Wat.	5620	7.0	40-60	Soybeans Corn Peanuts

Continued

Common Name	Trade Name	Predominant Transport Mode	Toxicity LD_{50} (mg/kg)	Toxicity LC_{50} (mg/l)	Approximate Persistance in Soil (days)	Crop Use
Cyanazine+	Bladex	Sed. Wat.	288	4.9	U	Corn
Dalapon+	Dowpon, Busfapon	Wat.	970	>100	15-30	Trees Small Fruits
Dicamba+	Banvel	Wat.	1707	35	U	Corn Sorghum Pastures
Dichlobenil	Casoron	Sed.	3160	10-20	60-180	Trees Small Fruits
Dinoseb+	Premerge	Sed. Wat.	40-60	0.4	15-30	Soybeans Peanuts
Diphenamid+	Enide or Dymid	Wat.	1000	25.0	90-180	Peanut Tobacco
Diuran+	Karmex	Sed.	3400	>60	200-500	Trees Small Fruits
Dyanap	Ancrack	Wat.	high tox.	U	U	Soybeans Peanuts
EPTC	Eptam	Sed. Wat	1630	19.0	30	Corn
Eradicane		U	2000-2870	U	U	Corn
Fluchloralin*	Basalin	U	1550	U	U	Soybeans Peanuts
Fluazifop-butyl	Fusilade	U	2451	U	U	Trees Small Fruits
Glyphosate	Roundup	Sed. Wat	4320	low tox.	150	Corn Sorghum Trees Small Fruits

Continued

Common Name	Trade Name	Predominant Transport Mode	Toxicity LD_{50} (mg/kg)	Toxicity LC_{50} (mg/l)	Approximate Persistance in Soil (days)	Crop Use
Isopropalin	Paarlan	Sed.	>5000	Toxic	150	Tobacco
Linuron	Lorox	Sed.	4000	16.0	120	Corn Sorghum Soybeans
Metolachlor[+]	Dual, Bicep	Wat. Sed.	2780	U	U	Corn Sorghum Peanuts Soybeans
Metribuzin[+]	Lexone or Sencor	Wat.	1100-2300	>1000	150-200	Soybeans
Napropamide	Devrinol	U	>500	U	U	Tobacco Trees Small Fruits
Naptalam	Alanap	Wat.	8200	>180	20-60	Peanuts
Norflurazon	Zorial	Sed.	>8000	U	U	Trees Small Fruits
Oryzalin	Surflan, Dirimal	Sed.	>10000	low tox.	U	Soybeans Trees Small Fruits Tobacco
Paraquat**	Gramoxone	Sed.	150	400	>500	Corn Sorghum
Pebulate	Tillam	Sed.	921-1900	Toxic	150	Tobacco
Pendimethalin	Prowl	Sed.	1250	U	U	Corn Peanuts Tobacco Soybeans

Continued

Common Name	Trade Name	Predominant Transport Mode	Toxicity LD_{50} (mg/kg)	Toxicity LC_{50} (mg/l)	Approximate Persistance in Soil (days)	Crop Use
Picloram**+	Tordon, Grazon	Wat.	8200	2.5	550	Pasture
Pronamide**+	Kerb	Sed.	8350	U	60-270	Trees Small Fruits
Propachlor*	Ramrod	Wat.	710	1.3	30-50	Sorghum
Propazine+	Milogard	Sed.	5000-7000	>100	200-400	Sorghum
Sethoxydim	Poast	U	3200-3500	U	U	Trees Small Fruits
Simazine**+	Princep	Sed.	>5000	low tox.	150	Corn Trees Small Fruits
Sodium Chlorate	Atratol Atlacide	U	4450-6250	Toxic	U	Sorghum
Terbacil+	Sinbar	Wat.	>5000	86	700	Trees Small Fruits
Trifluralin	Treflan	Sed.	>10000	0.1	120-180	Soybeans
Vernolate	Vernam	Sed. Wat.	1780	9.6	50	Soybeans Peanuts
2,4-D+	Decamine, Formula 40	Sed.	375	15	10-30	Corn Sorghum Pastures Trees Small Fruits
2,4-DB	Butyrac, Butoxone	Sed.	700	4.0	U	Peanuts

Table 5. Insecticides and Potential Water Pollution

Common Name	Trade Name	Predominant Transport Mode	Toxicity LD_{50} (mg/kg)	Toxicity LC_5sub0. (mg/l)	Crop Use
Acephate	Orthene	Wat. Sed.	866-945	U	Soybeans Peanuts Tobacco
Aldicarb (A)(N)**+	Temik	Wat. Sed.	0.9	U	Soybeans Peanuts Tobacco
Azinphos-Methyl**	Guthion	Sed.	5-2-	0.01	Soybeans Tobacco Trees Small Fruits
Bacillus thuringiensis	Bactur, Dipel	Sed.	Non-Toxic	U	Tobacco
Carbaryl	Sevin	Sed. Wat.	246-283	U	Corn Soybeans Peanuts Tobacco Sorghum
Carbufuren (N)**+	Furadan	Wat.	11	0.21	Corn Sorghum Peanuts Tobacco
Carbophenothion (A)	Trithion	Sed.	6.9-36.9	0.23	Corn Sorghum Soybeans

Continued

Common Name	Trade Name	Predominant Transport Mode	Toxicity LD_{50} (mg/kg)	LC_{50} (mg/l)	Crop Use
Chlorphyrifos**	Lorsban, Brodan	U	96-270	0.02	Corn Sorghum Soybeans Peanuts Trees Small Fruits
Cyhexatin (A)	Plictran	U	540	U	Trees Small Fruits
Demeton (A)**	Systox	Wat.	2.5-6	0.081	Trees Small Fruits
Diazinon (N)	Spectracide	Sed. Wat.	300-400	0.03	Corn Sorghum Tobacco Trees Small Fruits
Dicofol (A)	Kelthane	Sed.	830-960	0.10	Trees Small Fruits
Dimethoate (A)	Cygon, DeFend	Wat.	2.5	9.6	Corn Soybeans Trees Small Fruits Sorghum
Disulfoton (A)**+	Di-Syston	Sed.	2-12	0.04	Corn Sorghum Tobacco Soybeans Peanuts

Continued

Common Name	Trade Name	Predominant Transport Mode	Toxicity LD_{50} (mg/kg)	Toxicity LC_{50} (mg/l)	Crop Use
Endosulfan (A)	Thiodan	Sed.	30	0.001	Tobacco Trees Small Fruits
Ethion (A)	Fosmite	Sed.	208	0.23	Corn Sorghum
Ethoprop (N)**	Mocap	Sed.	61.5	1.0	Corn Sorghum Tobacco Peanuts
Fensulfothion (N)	Dasanit	Sed. Wat.	2-10	0.15	Corn Sorghum Tobacco
Fenvalerate**	Pydrin, Ectrin	U	451	U	Corn Sorghum Peanuts Soybeans
Fonofos**	Dyfonate	Sed.	8-17.5	0.03	Corn Sorghum Peanuts Tobacco
Formetanate (A)	Carzol	Sed. Wat.	20	U	Trees Small Fruits
Malathion	Cythion, Celthion	Wat.	1375	0.019	Corn Sorghum Tobacco Peanuts Soybeans
Metaldehyde	Metason	Wat.	250-1000	> 100	Tobacco

Continued

Common Name	Trade Name	Predominant Transport Mode	Toxicity LD_{50} (mg/kg)	LC_{50} (mg/l)	Crop Use
Methidathion (A)**	Supracide	Wat.	44	U	Tobacco Trees Small Fruits
Methiocarb (A)**	Mesurol	Sed.	10-35	U	Corn Sorghum
Methomyl**+	Nudrin, Lannate	Sed. Wat.	17	0.9	Corn Sorghum Soybeans Peanuts Tobacco Trees Small Fruits
Methyl Parathion	Penncap- M	Sed. Wat.	9-25	1.9	Corn Sorghum Tobacco Soybeans
Monocrotophos (A)	Azodrin	Wat.	8-23	7.0	Peanuts Tobacco
Oxamyl (N)(A)+	Vydate	Wat.	5.4	U	Tobacco
Parathion**	Bladan	Sed.	4-13		Trees Small Fruits
Permethrin**	Ambush, Pounce	Sed.	> 4000	U	Corn Sorghum Soybeans
Phorate**	Thimet	Sed. Wat.	2-4	0.006	Corn Sorghum Peanuts Soybeans

Continued

Common Name	Trade Name	Predominant Transport Mode	Toxicity LD_{50} (mg/kg)	Toxicity LC_{50} (mg/l)	Crop Use
Phosalone (A)	Zolone	Sed.	120	3.4	Trees Small Fruits
Phosmet	Imidan	Sed.	147-316	0.03	Trees Small Fruits
Phosphamidon**	Dimecron	Wat.	17-30	8.0	Trees Small Fruits
Propargite (A)	Comite	U	2200	0.03	Peanuts Trees Small Fruits
Terbufos (N)**	Counter, Contraven	Sed. Wat.	35	U	Corn Sorghum
Toxaphene**	Attac, Motox	Sed.	69	0.003	Corn Sorghum
Trichlorfon	Dylox, Proxol	Wat.	150-400	0.16	Corn Sorghum Tobacco

Table 6. Fungicides and Potential Water Pollution

Common Name	Trade Name	Predominant Transport Mode	Toxicity LD_{50} (mg/kg)	Toxicity LC_{50} (mg/l)	Crop Use
Benomyl	Benlate, Tersan	Sed.	> 10000	0.5	Soybeans Peanuts Trees Small Fruits
Captan	Orthocide	Sed.	9000	0.13	Corn Sorghum Peanuts Trees Small Fruits
Captafol	Difolatan	Sed.	5000-6200	0.03	Peanuts
Carboxin	Vitavax	Sed. Wat.	3820	2.2	Corn Sorghum Soybeans Peanuts
Chlorothalonil	Bravo	U	> 10000	U	Soybeans Peanuts
Dichloran	DCNA, Botran	U	> 5000	U	Peanuts
Dikar (A)		U	> 5000	U	Trees Small Fruits

Continued

Common Name	Trade Name	Predominant Transport Mode	Toxicity LD_{50} (mg/kg)	LC_{50} (mg/l)	Crop Use
Dinocap (A)	Karathane	Sed.	980	0.14	Trees Small Fruits
Dodine	Cyprex	Sed. Wat.	1000	U	Trees Small Fruits
Ferbam	Carbamate	Sed. Wat.	> 17000	12.6	Tobacco Trees Small Fruits
Folpet	Phaltan	Sed.	> 10000	15.6	Trees Small Fruits
Maneb	Dithane M-22	Sed. Wat.	8000	1.0	Peanuts Tobacco Trees Small Fruits
Mancozeb	Manzate, Dithane M-45	Sed.	11200	U	Peanuts Trees Small Fruits
Metalaxyl	Apron, Ridomil, Subdue	Wat.	669	U	Soybeans Tobacco
Metiram	Polyram	U	> 10000	U	Trees Small Fruits

Continued

Common Name	Trade Name	Predominant Transport Mode	Toxicity LD_{50} (mg/kg)	Toxicity LC_{50} (mg/l)	Crop Use
PCNB	Folosan	U	1700	U	Peanuts Soybeans
Thiabendazole	Mertect	U	3100	U	Soybeans
Thiophanate	Topson M	U	> 15000	U	Soybeans Peanuts Trees Small Fruits
Thiram	AAtack, Arasan	Sed.	780	0.79	Corn Sorghum Peanuts Trees Small Fruits
Triadimefon	Bayleton	Sed. Wat.	1020-1855	U	Trees Small Fruits
Triforin	Funginex	Sed. Wat.	> 16000	U	Trees Small Fruits
Zineb	Dithane Z-78	Sed.	> 5200	0.5	Tobacco Trees Small Fruits

Virginia Pesticide Law[1]

- A Brief Review -

Article 1. Title, Definitions and General Considerations.

Article 2. Registration

Article 3. Prohibited Acts, Penalties and Proceedings in Case of Violations.

Article 4. Virginia Pesticide Use and Application Act of 1975.

Article 5. Marine Antifoulant Paints

Highlights of the Virginia Pesticide Law

- Every pesticide which is manufactured, distributed, sold, or offered for sale, used or offered for use within this state or delivered for transportation or transported in interstate commerce or between points within this state through any point outside Virginia shall be registered with the Commissioner of Agriculture (§ 3.1-220).

- The Commissioner may register and permit the sale and use of any such pesticide which has been duly registered under the provisions of FIFRA, as amended, but products so registered shall be subject to the inspection fees provided for herein, and to all other provisions of the chapter (§ 3.1-222).

- The registrant, before manufacturing, distributing, selling, offering for sale, or offering for use any pesticide in Virginia, shall register each brand or grade of such pesticide with the Virginia Department of Agriculture and Consumer Services upon forms furnished by the Department. For purposes of defraying expenses connected with the enforcement of this chapter, he shall pay to the Department an annual inspection fee of ten dollars for each and every brand or grade to be offered for sale or use in this State, whereupon there shall be issued to the registrant by the Department a certificate entitling the registrant to manufacture, distribute or sell all duly registered brands in this State until the expiration of the certificate. All certificates shall expire on December 31 of each year unless otherwise terminated, and are subject to renewal upon receipt of annual inspection fees (§ 3.1-227).

- No private applicator shall use any pesticide classified for restricted use unless such person has first obtained certification from the Commissioner in accordance with the certification standards for private applicators established by the Board (§ 3.1-249.6).

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[1] Virginia Department of Agriculture and Consumer Services, The Michie Company, Charlottesville, Virginia, 1987.

- The Commissioner may cooperate, receive grants-in-aid, and enter into agreements with any agency of the federal government, of this State or its subdivisions, or any agency of another state, in order to:

  (i) secure uniformity of regulations;

  (ii) cooperate in the enforcement of the federal pesticide control laws through the case of state and federal personnel and facilities and to implement co-operative enforcement programs;

  (iii) develop and administer state programs for training and certification of certified applicators, meeting but not limited to, federal standards;

  (iv) contract for training with other agencies including federal agencies for the purpose of training certified applicators;

  (v) contract for monitoring pesticides in the environment;

  (vi) prepare and submit state plans and reports to meet federal regulations and certification standards; and

  (vii) regulate certified applicators (§ 3.1-249.20).

- In order to further protect the citizens of Virginia and to provide additional economic and environmental protection, the Board of Agriculture is authorized, after a public hearing following due notice, and upon proof satisfactory to the Board, to prescribe appropriate rules, regulations, and standards to restrict or prohibit the sale or use and disposal of any pesticide which:

  (i) undesirably persists in the environment and/or increases due to biological amplification or otherwise poses environmental hazards; or

  (ii) may be contrary to the public interest because of toxicity and/or inordinate hazard to man, animal or plant.

  After each action, the Board shall prepare a memorandum highlighting the evidence reviewed and the reasons for action taken as well as any other matter which the Board deems relevant (§ 3.1-217.1).

Pesticides Waste Disposal Regulations in Virginia

- A Brief Review -

In the State of Virginia, the Virginia Department of Waste Management is responsible for the enforcement of the Resource Conservation and Recovery Act (RCRA).

Highlights of Virginia Regulations

- The regulations apply to businesses that produce as little as 220 pounds (100 kg) or 27.5 gallons of hazardous waste each month.
- All hazardous waste generators should notify and be registered by the Virginia Division of Solid and Hazardous Waste Management and obtain an EPA identification number.
- All hazardous wastes for shipment should be packed following the rules set by the United States Department of Transportation (DOT). In Virginia, these rules are described under the Virginia Regulations for the Transportation of Hazardous Materials.
- All hazardous wastes generated should be sent to an approved disposal facility. Only a licensed, permitted-in-Virginia hazardous waste transporter may transport hazardous wastes to the disposal facility. It is the waste generator's responsibility to locate and contract with a transporter and a disposal facility. However, under the law, the waste generator is always responsible and liable for the proper disposal of hazardous wastes.
- The Uniform Hazardous Waste Manifest form should accompany containers of hazardous waste from the time they leave the source until they reach a disposal facility. (Note: The EPA has created a form for the Uniform Hazardous Waste Manifest. States may adopt EPA form 8700-22, or they may design their own form as long as it contains the same information. Virginia has chosen to use the EPA form).
- A small quantity waste generator may accumulate up to 6,000 kilograms (13,200 pounds) or thirty 55 gallon drums of liquid hazardous wastes for 180 days (six months). If the waste needs to be shipped more than 200 miles for disposal, these quantities may be stored up to 270 days (nine months).
- Unless a waste generator has a special license, the law strictly prohibits the following activities:
  - Storing any hazardous wastes other than those generated at a particular plant;
  - Consolidating wastes at one place of business, for example, wastes from a generator with more than one plant; and
  - Accepting other business's wastes, even temporarily.
- The legal penalties for violating the law are to pay fines of up to $10,000 per day for each violation of the law. In addition, a criminal violation of the law may include a prison sentence of one year for each violation.

Federal Pesticides Law[1]

- A Brief Review -

Chronology

1910 - Federal Insecticide Act of 1910. The Act dealt only with labeling offenses such as adulterating or mislabeling a product. The Act did not address the safety of pesticide products. The highest fine for violations was $300.

1947 - The Congress approved the first version of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). The Act's mandate was to protect consumers from ineffective products. The United States Department of Agricultural (USDA) handled all pesticide regulations.

1954 - The Food and Drug Administration (FDA) was given authority under the Federal Food, Drug, and Cosmetic Act (FFDCA) to establish pesticide residue tolerances, or allowable limits for pesticide residues on food and animal feed. Note: The authority to set such tolerances now is carried out through a complicated cooperative scheme whereby FDA sets pesticide residue limits for processed foods, USDA sets limits for edible portions of meat, and the United States Environmental Protection Agency (EPA) sets limits for raw (unprocessed) meat and agricultural products. FDA enforces most of the limits, although USDA enforces some tolerances under its meat inspection program.

1964 - The Congress amended FIFRA to eliminate the loophole that allowed marketing of unregistered products. The amendment allowed USDA to deny or suspend registrations. However, the Act's major purpose was still to protect consumers from ineffective products.

1970 - Jurisdiction of FIFRA was passed from USDA to the newly formed United States Environmental Protection Agency. The pesticide regulatory staffs of USDA and FDA were consolidated and incorporated into the newly created EPA.

1972 - FIFRA was amended to change its focus from efficacy to safety. The Federal Environmental Pesticide Control Act of 1972, PL 92-516 provides the format for pesticide regulations as they exist today. This version of the law established by 1972 amendments is referred to as FIFRA.

1975 - The amendments of 1975 required EPA to submit proposed pesticide cancellations to a scientific review panel and to the Secretary of Agriculture. The agency is also required to weigh the effect of its decision to cancel a pesticide against the effect of the cancellation on food production and prices. Note: FIFRA is unusual among federal environmental laws in requiring EPA to con-

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[1] Pesticides: State and Federal Regulation, A BNA Special Report, The Bureau of National Affairs, Inc., 1987.

sider not only the risks posed by a pesticide, but also its economic, social, health, and environmental benefits.

1978 - The amendments of 1978 addressed problems EPA was encountering in re-registering many old pesticide products. The amendments allowed EPA to group the pesticides by active ingredients and register them on a generic rather than an individual product basis.

Federal Regulations for Pesticide Waste Disposal

- A Brief Review -

In 1981, 15.6 billion gallons (58 million metric tons) of pesticide waste were disposed of in the United States (Friedman, 1984). Wastes containing pesticides originate from several sources. These include wastes generated from manufacturing, testing, and formulation of pesticides; wastes from the "empty" containers; wastewater generated from rinsing commercial aerial applicators; and old and cancelled pesticides which should be disposed of. Numerous disposal and treatment technologies are available for pesticide wastes. These practices include land disposal, incineration, open burning, physical and chemical treatment, and biological treatment. The application of these methods to pesticide wastes is regulated by the provisions of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) of 1972 and the Resource Conservation and Recovery Act (RCRA) of 1976.

The FIFRA amendments of 1972, section 19 state that, "The administrator (EPA) shall establish procedures and regulations for the disposal or storage of packages and containers of pesticides, and accept at convenient locations for safe disposal a pesticide the registration of which is cancelled under section 6(c) if requested by the owner of the pesticide." Section 19 was further modified in 1978 to require information on disposal to accompany all cancellation orders. Another section of FIFRA which concerns pesticide waste disposal is the labeling requirements (40 CFR 162.10). Section 12(a) (2) (g) of FIFRA states that it is unlawful to use any pesticide in a manner inconsistent with its labeling, and disposal has been determined to be part of the use process.

Pesticide wastes can be partially regulated under the provisions of RCRA if they are identified as hazardous wastes. A waste may be defined as hazardous under RCRA if it meets certain criteria for ignitability, corrosivity, reactivity, or toxicity, or if the waste is specifically identified by EPA as a hazardous waste. An individual waste stream is subject to classification as hazardous if it contains any one of approximately 375 chemicals identified by EPA as hazardous constituents. Pesticide wastes that are hazardous by reason of the characteristics are either: solvent based and have a flash point $<60°C$; are aqueous and have a pH <2.0 or >12.5; or release HCN or H_2S upon contact with acids. Toxicity characteristics of hazardous waste as defined by RCRA (referred to as extraction procedures of EP toxicity) is based on threshold concentrations of eight metals and six pesticides in an extract of the waste. Sixteen of the specific hazardous waste streams listed by EPA result from the manufacture of nine specified pesticides. Of the approximately 375 listed chemicals about one-fifth are pesticide active ingredients.

The RCRA regulations exempt from regulatory control persons who generate or accumulate less than 100 kg per month of hazardous waste.

Under the exemption clause, farmers are not required to comply with the RCRA notification of management standards as long as empty pesticide containers are triple rinsed and the pesticide residues are disposed of on the farm in a manner consistent with the disposal instructions on the pesticide label. However, this RCRA exemption does not apply to commercial pesticide applicators.

The RCRA regulations also provide standards for construction and operation of certain disposal facilities. All facilities engaged in the treatment, storage, or disposal of hazardous wastes including hazardous pesticides must be permitted by either EPA or an authorized state (40 CFR 264,265).

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