

A Pesticide Primer

A pesticide is defined as any substance that is used to kill or otherwise control a pest. The term “pesticide” includes insecticides, herbicides, fumigants, fungicides, repellents, rodenticides, and disinfectants. About 940 million pounds of pesticidal active ingredients are applied yearly to agricultural land to control insects, weeds, fungi, nematodes, bacteria, and other crop pests (Aspelin and Gruber, 2000).

Pesticides in use in the U.S. today differ in significant ways from the pesticides relied on from the 1940's through the 1970's. DDT and several other organochlorine insecticides have long since been banned from use in this country. Although these older products tended to have low acute toxicity to humans, they had very long half-lives. Their persistence in the environment, coupled with their tendency to be stored in fat, allowed them to accumulate in living organisms and to bioconcentrate in the food chain.

By contrast, the newer pesticides tend to have shorter half-lives and to be water-soluble, so that they are excreted (primarily in urine) and are less persistent in the environment. However, the acute toxicity of some of the newer products (notably organophosphate insecticides) is much higher than the older products, making them more hazardous for users to handle. In addition, their increased water solubility has resulted in contamination of ground water as a result of improper application, poor well construction, improper disposal, or leaching. Whereas earlier pesticides were aimed at controlling a broad spectrum of pests, many pesticides today are far more specific in their action. Also, today's pesticides are effective at much smaller concentrations than in the past. Together, the latter two factors mean that many more different products are in use, but in a far smaller volume (ounces per acre, rather than pounds per acre) than in the past.

By volume, herbicides account for the majority of applications to agricultural crops. Other uses of pesticides include applications to: forests to control insects and understory vegetation; rights-of-way along railroads and under electric wires to control vegetation; boat hulls to control fouling organisms; houses, schools, and commercial and office buildings to control insects, rodents, and fungi; landscapes, parks, and recreational areas to control weeds, insects, and disease pests; aquatic sites to control mosquitoes and weeds; wood products to control wood-destroying organisms; food preparation areas to control insects and rodents; human skin to kill or repel insects; livestock to control insects and other pests; and other sites.

When used properly, pesticides can benefit humans and the environment. Pesticides control important crop pests, ensuring a plentiful and diverse food supply. They prevent disease in humans and animals, and control pests that infest homes, schools, hospitals, food warehouses, and other buildings.

The remainder of this paper provides an overview of the regulation of pesticides, effects of pesticidal formulations on potential absorption into the body, and patterns of exposure to pesticides.

Regulatory Context

In the United States, the Environmental Protection Agency (EPA) is responsible for regulation of pesticides. Pesticides may only be sold in the U.S. if EPA has reviewed and approved the manufacturer's application for registration, and determined that use of the product will not present an unreasonable risk to humans or the environment. A pesticide that passes EPA's scrutiny will be registered for use on specific crops or sites, and must be sold with specific label directions for how the product is to be used.

Nearly 900 active ingredients and more than 20,000 pesticide products are registered for use in the U.S. Each pesticide product consists of one or more active ingredients (the substance that kills or controls the pest) and may have one or more inert ingredients (substances for which no pest control claim is made). Inert ingredients are added for a number of reasons, such as to make the product safer or easier to apply, or to increase the efficacy of the active ingredient by making it last longer in the range of the target pest. Inert ingredients may also cause adverse effects in people and/or the environment.

A single active ingredient may be registered for different uses -- such as several different crops, a yard, and a food warehouse -- and the concentration, application method, and application rate may differ for each use. Also, products with the same active ingredient may include different inert ingredients. For some applications, such as to crops, pets, and livestock, pesticide usage patterns are seasonal. For other uses, such as structural pest control and greenhouse situations, pesticide applications may continue throughout the year. Pesticides may be applied as sprays, dusts, granules, baits, fumigants, injection systems, roll-on applications, shampoos or animal dips, and other methods.

Each active ingredient intended for use on food must have a **food tolerance** established. The tolerance is the legal amount of residue that may remain in or on the food at harvest. EPA sets a specific tolerance for each pesticide/crop, pesticide/meat, or pesticide/meat byproduct combination. Pesticides used on food or feed crops often have a pre-harvest interval (PHI) established by EPA that appears on the product label. The PHI is the amount of time that must pass before a treated crop can be harvested. The PHI is important in allowing time for the pesticide to degrade to a level at or below the legal tolerance.

In setting a tolerance, EPA considers the relative proportion of each food in the diet, as well as the acute and chronic toxicity of the active ingredient. Differences in the foods most relied on for infants and children's diets are also considered. Under the Food Quality Protection Act of 1996, EPA was charged with reviewing all tolerances for existing pesticides within ten years to determine that they pose a "reasonable certainty of no harm" from aggregate and cumulative exposures. Aggregate exposure refers to

exposures from all sources, including residues in food and drinking water, occupational exposures, and incidental exposures. Cumulative exposure refers to exposure to different pesticides that share a common mechanism of action.

Pesticides that pose a hazard to people and/or the environment even when used according to label directions are classified by EPA as **restricted use pesticides (RUP)**. These products may be purchased and used only by certified applicators, or by someone under the supervision of a certified applicator. Certified applicators have received instruction in the proper use of RUPs. All other pesticides are available for sale to, and use by, anyone without special training.

Pesticides are designed to be toxic to the pests they control, but they may also pose risks to humans and wildlife. Therefore, it is extremely important that pesticides be used only in strict accordance with the label. A pesticide should never be used on a crop, plant, or site for which it is not labeled, and should never be applied more frequently or at a different rate than the label allows. Potential risks can be minimized by choosing alternative measures when feasible; using pesticides sparingly; wearing the proper protective gear (as indicated on the label); and applying, storing, and disposing of pesticides properly.

Exposure and Absorption

There are three main routes of exposure: oral, inhalation, and dermal. (Eye exposure is considered a special type of dermal exposure.) Most pesticide active ingredients can be absorbed to some extent by all three routes, but the formulation of a product has a large effect on potential absorption:

- **Emulsifiable concentrates** (liquid active ingredient with one or more petroleum-based solvents and an agent that allows the product to form an emulsion when mixed with water) and **ultra-low-volume concentrates** (products that may approach 100% active ingredient and are designed to be used as is or diluted with only very small quantities of water) are easily absorbed through the skin.
- **Wettable powders** (dry, finely ground formulations designed to be mixed with water) are less easily absorbed than emulsifiable concentrates and other liquid pesticide formulations, but the powder may be inhaled during the mixing/loading process.
- **Dusts** (low percentage of active ingredient plus a very fine, dry, inert carrier made from talc, chalk, clay, nut hulls, or volcanic ash) are applied as dry material and are less easily absorbed through the skin but are easily inhaled.
- **Granules** (low percentage of active ingredient with larger, heavier absorptive materials such as clay, corn cobs, or walnut shells forming the carrier) are also applied dry but pose less risk of inhalation.

- **Baits** (low percentage of active ingredient mixed with food or another pest-attractive substance) may pose an ingestion hazard if they are placed where children or pets can access them.

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Pesticide Quick Facts

- There are 3 to 4.5 million farmworkers in this country and a million or more pesticide applicators who are often at greater risk for pesticide exposure because of mixing or applying pesticides or working in fields where pesticides are applied.
- Based on states with required reporting of pesticide-related health concerns, EPA estimates there are approximately 250-500 physician-diagnosed cases occur per 100,000 agricultural workers (including pesticide handlers) (Blondell, 1997).
- Migrant and seasonal farmworkers are especially at high risk since they often work and live in poor occupational environments where pesticide exposures can be significant.
- A 1990 EPA survey estimated that 84% of American households used pesticides, most commonly insecticides (Whitmore et al, 1992). Homeowners annually use 5-10 pounds of pesticide per acre on their lawns and gardens, many times the amount applied by farmers to corn and soybean fields (Robinson et al, 1994).
- Disinfectants are a widely-used source of non-agricultural pesticide use (e.g., pine oil cleaners, bathroom cleaning products, and cleaning materials for swimming pools). In addition, work-related exposures for structural pest control operators and workers in nurseries, greenhouses, and landscaping are also of concern in the non-agricultural sector.
- Organophosphate and pyrethroid insecticides are the categories of pesticides most often implicated in acute pesticide-related illnesses reported to poison control centers.

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Patterns of Exposure

Two types of exposure patterns are considered here: occupational exposures and incidental exposures.

Occupational Exposures

People who work in manufacturing or distribution plants for pesticide products have the most *potential* exposure to pesticides, but they often have relatively low *actual* exposure as a result of the installation of engineering controls at the facilities and use of

personal protective equipment (PPE). Wettable powders and most liquid pesticide products, except those specifically designed for use by homeowners, require dilution with water, oil, or other solvent prior to application. Those who mix and load the concentrates into the application equipment also have a high potential for exposure, especially if they do not wear the PPE designated on the product label. Farm workers, migrant laborers, and others who must reenter treated areas to perform tasks such as cultivation, harvest, irrigation, and equipment maintenance may be exposed to small amounts of pesticide residues remaining on the plants, but their jobs may require them to spend more time in the treated area than the applicator.

To keep exposures at safe levels, the pesticide product label specifies whether PPE must be worn; the length of time that workers must wait after treatment before reentering a treated area without PPE (called the re-entry interval or REI); and whether training is required for workers and pesticide handlers on farms, forests, greenhouses, and nurseries. The REI applies only to workers, not to the general public. For instance, consumers may be allowed to enter and pick in a treated strawberry field, whereas farm workers would not be allowed in until the REI had passed. The rationale is that workers may be in the field eight hours per day for many days, while a consumer would only be in the field for a short period of time. Thus, the potential exposure for a worker is much greater than for the consumer.

The type of equipment used in applying pesticides provides different opportunities for exposure. The selection of equipment varies with the crop or site, the formulation of the product, the pest being targeted, the pesticide chosen, and the economic situation of the applicator or business. Airplanes and helicopters, tractor-mounted sprayers, backpack sprayers, canister sprayers (commonly referred to as B&G type), granular spreaders, and other equipment may be used. Some application equipment, such as closed cab systems where the operator is separated from the surrounding environment, provides very good protection from exposure. Sometimes pesticides can be loaded through closed systems, where there is very little opportunity for exposure of the mixer/loader. Many structural applications of liquid pesticides call for crack and crevice treatment, i.e., a stream of pesticide is directed into the angles formed where floors and walls meet or other such corners along which pests run, rather than a broadcast or space spray. Homeowners usually have the least specialized application equipment, but they are usually applying dilute materials.

Many types of personal protective equipment are available, and label directions specify what equipment must be worn when performing specific tasks, such as mixing and loading, applying, or reentering treated areas. In general, the hands and forearms receive the most exposure. Depending on the application equipment, splashback may occur to the lower legs, drift may fall on the head and ears, or a vortex effect may be generated, resulting in contamination of the back of the neck. A full protective suit, gloves, respirator, hood, and boots, while providing excellent pesticide protection, constitutes a very hot outfit and may present a heat stress hazard. Applicators may also be overexposed if equipment is not properly maintained, e.g., when respirator filters are not changed often enough, etc.

Incidental Exposures

Outside of occupational exposures, people may be exposed to pesticides through residues in foods and water; in and around their apartment buildings, homes, and yards; in their office buildings; schools, or public buildings; and at recreational areas. National attention is focusing interest on **integrated pest management** (IPM) strategies rather than conventional pesticide treatments in and around schools and public buildings. Long utilized in many agricultural systems, the IPM approach combines physical, cultural, biological, and other means of pest control as well as the use of pesticides to minimize the potential adverse effects on human health and the environment, and to improve pest detection, quantification of threshold levels for treatment, placement of pesticide, and timing of applications in the interests of maximizing crop yield, aesthetic benefits, and public health. Pesticides may be needed, for instance, to control cockroaches and rodents in school cafeterias, but they may be applied as baits contained in bait stations, with little opportunity for exposure of children and staff. Herbicides are frequently needed to control weeds on athletic fields to prevent potential injuries associated with uneven playing surfaces, but they may be applied as spot treatments rather than broadcast applications.

Many homeowners have herbicides and fungicides applied to their lawns throughout the growing season either by themselves or by commercial firms. On a per-acre basis, homeowners use many times more pesticide (5-10 lbs/acre annually) than the amounts applied on agricultural land (Robinson et al, 1994). Consumers also use insecticides, herbicides, and fungicides on their own fruit and vegetable gardens and inside their homes and apartments. Because members of the general public do not have special training or knowledge about the proper use of pesticides, they may be more likely to misuse pesticides than trained commercial applicators. They may use a pesticide at a higher rate or more often than the label allows.

Another problem is use of a pesticide on a site for which the product is not registered, e.g., application of pesticides labeled for use on ornamentals to vegetable and fruit gardens, or use of a pesticide labeled for outdoor application only to areas inside homes or apartments. Some products are not registered for additional sites only because there has been no particular need for them (for instance, if more effective products already exist for such use), but in other cases, the product is not registered for a particular site because it would present a hazard. A common source of accidental exposure in the home is improper storage of household pesticides. Children and others have also been injured when empty pesticide containers have been re-used for other purposes, as residues remain in the containers.

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Pesticide-Related Laws and Regulations

Two federal laws, the Federal Insecticide, Fungicide, and Rodenticide Act, and the Food Quality Protection Act, are responsible for most of the regulation of the use of pesticides in the U.S. Some other laws have a minor role in regulation of pesticides. The basic provisions and health-related requirements of the basic laws and regulations pertaining to pesticides are outlined below. However, health care providers should be aware that states and local jurisdictions may pass their own laws or regulations, which may be stricter but cannot be less strict, than the federal laws.

Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)

When FIFRA was first passed in 1947, it established procedures for registering pesticides with the U.S. Department of Agriculture and established labeling provisions. The Act has been significantly amended, and in its current form, FIFRA mandates that the U.S. Environmental Protection Agency (EPA) regulate the use and sale of pesticides to protect human health and preserve the environment.

- Defines “pesticide” as any substance intended for preventing, destroying, repelling, or mitigating any pest. Includes insecticides, fungicides, rodenticides, herbicides (weed killers), avicides, plant regulators, defoliants, desiccants, bactericides, disinfectants, etc.
- Requires any substance sold with pesticidal claims must first be registered with EPA. To register a pesticide, the manufacturer must submit a battery of toxicological tests: acute, subchronic, chronic; reproductive, mutagenic, carcinogenic, and (under FQPA -- see later) endocrine effects.
- Provides for classification of pesticides based on potential for harm. Most pesticides can be bought and used by anyone. However, if EPA determines that a pesticide, even when used according to label directions, may cause unreasonable effects on human health or the environment, that pesticide, or the uses in question, is classified for restricted use. A restricted use pesticide may be purchased and used only by a certified pesticide applicator, i.e., one who has received training and passed an exam on the proper use of pesticides, or under the direction of a certified applicator.
- Institutes the pesticide label as the law. Labeling requirements control when and under what conditions pesticides can be applied, mixed, stored, loaded or used, fields can be reentered after application, and crops can be harvested. Any use not in strict accordance with the label

directions (i.e., site, rate, or method of application; number of times applied during a season; interval between last application and harvest -- the preharvest interval; number of hours or days between application and reentry -- the restricted entry interval; use of protective gear; etc.) is a misuse and the applicator may be subject to financial penalty and/or prison.

- Provides that food or feed residues which lack tolerances or have residues exceeding the established tolerances (see FFDCA, below) are subject to seizure, and the applicators or agricultural producers are subject to prosecution under FIFRA if misuse is found. There are several possible causes of exceeding a tolerance, including use of a pesticide labeled for the crop but applied at a higher rate or more times per season than the label allows; application of a pesticide for which no tolerance has been established on the crop because no practical reason for its use on the crop exists, or because the manufacturer has not requested a tolerance; drift of a pesticide applied to a crop which is a labeled site onto a crop which is not a labeled site and thus does not possess a tolerance.
- Provides for EPA to take action against pesticides considered to present an unacceptable risk. If EPA finds that a registered pesticide poses potential unacceptable risk to humans or the environment, the agency may reduce risk through requiring changes on the label (e.g., lower rate of application, fewer applications per season, increased protective gear, longer restricted entry interval, prohibition on grazing of treated fields, etc.). If such risk mitigation measures would not reduce the risk, the Agency may cancel some or all uses of the product.
- Designates EPA as ultimate authority over the use of pesticides. However, each state has its own enforcement agency, designated the "state lead agency," which serves as the primary enforcer and to which any suspected misuses of pesticides should be reported. States may also enact additional pesticide laws and regulations. Tribes also have separate authority.

Federal Food, Drug, and Cosmetic Act (FFDCA)

FFDCA is the basic food and drug law in the U.S. and is administered by the Food and Drug Administration (FDA).

- Establishes the concept of a tolerance (the maximum legally permissible level of residue at harvest) for pesticide residues in or on human food and animal feed. Tolerances are specific to a pesticide/commodity combination.
- Requires EPA to establish these residue tolerances for pesticides in or on animal food, feed, and byproducts.

- Allows seizure of any domestic or imported food or feed found to have a pesticide residue above the tolerance level, or for which no tolerance has been set in the U.S.

Food Quality Protection Act (FQPA)

This law was passed by Congress in 1996 with the aim of improving regulations on pesticide registration and use, especially with regard to providing protections for children. FQPA amended FIFRA and FFDCA and fundamentally changed the way EPA regulates pesticides. The Act has broad implications that extend beyond pesticides in food.

- Establishes a health-based standard -- reasonable certainty of no harm -- that must be applied to all pesticides used on foods. Requires that all existing pesticide tolerances be reviewed within 10 years of enactment of FQPA (*i.e.*, by 2006) to make sure they meet the requirements of the new health-based safety standard.
- Requires EPA to periodically review pesticide registrations, with a goal of establishing a 15-year cycle, to ensure that all pesticides meet updated safety standards.
- Requires consideration of cumulative exposure (total exposure resulting from pesticides with the same mode of action) and aggregate exposure (total exposure resulting from the sum of dietary exposures, occupational exposures, incidental exposures, and exposures through contaminated drinking water) in setting tolerances.
- Provides extra protection for infants and children: requires an explicit determination that tolerances are safe for children; includes an additional safety factor of up to 10-fold, if necessary, to account for uncertainty in data relative to children; requires consideration of children's special sensitivity and potential exposure to pesticides.
- Incorporates provisions for endocrine testing.

Worker Protection Standard (WPS)

This EPA regulation applies to farms, forests, nurseries, greenhouses, and related structures. It provides special protections to pesticide applicators, mixer/loaders, and persons who may be exposed to pesticide residues on the job in these operations.

- Provides protections to two types of workers: pesticide handlers and agricultural workers. Pesticide *handler* includes employees who mix, load, or handle open pesticide containers; apply pesticides; incorporate soil-applied pesticides; work on pesticide application equipment; act as a flagger, or work as a scout on treated fields or sites. Agricultural *worker* includes employees who perform tasks such as harvesting, weeding, cultivating, watering, pruning, etc. related to the production of an agricultural plant.
- Requires employers to:

- Provide workers and handlers information about pesticide applications, including an application list, emergency information. Employees must also have access to product-specific information.
- Post a pesticide safety poster at a central location.
- For some pesticides (designated on the label), provide oral warnings about pesticide applications as well as on-site posting are required.
- Ensure that both handlers and workers receive pesticide safety training within a specified period of time in a language they can understand. EPA-developed and/or approved training materials are available for training.
- Make available certain personal protective equipment (PPE) to handlers and certain workers.
- Observe restricted entry intervals, during which no one except properly trained and clad individuals are allowed back into a treated site.
- Make decontamination sites available. For both handlers and workers, the decontamination site must provide soap, towels, and clean water. For handlers, the site must additionally provide water for washing the entire body, a clean change of clothes, and emergency eye flushing water.
- Provide emergency assistance in the form of product information and transportation to a treatment site (clinic, hospital, etc.).

Farm Bill of 1990

Under the provisions of this bill, certified private and commercial applicators must maintain records of all pesticides they apply. Some state laws and regulations broaden these requirements.

- Mandates record *keeping*, not record *reporting*.
- Requires records to be maintained for a period of two years after application and to be made available to health care providers upon request.

Occupational and Safety Health Act (OSH Act)

Congress passed the OSH Act in 1970 (and amended it in 1990) to ensure worker and workplace safety. Their goal was to ensure that employers provide their workers a place of employment free from recognized hazards to safety and health, such as exposure to toxic chemicals, excessive noise levels, mechanical dangers, heat or cold stress, or unsanitary

conditions. The OSH Act applies to virtually all private employers in the U.S. with more than 10 employees.

- Provides the Occupational Safety and Health Administration (OSHA) authority over manufacturing, formulating, and distribution operations involving worker safety in the pesticide industry. EPA has authority under FIFRA and WPS (see above) relating to safety of workers in areas treated with pesticides. Workers at farms or businesses employing more than 10 individuals may also be subject to OSHA requirements.
- Establishes a Right-to-Know law, whereby employers must furnish employees exposed on the job to hazardous chemicals with information on those hazards. Labels, MSDS, training, and access to written records are to be used to comply with the law.
- Defines confined space entry rules. Employers must identify confined spaces in the workplace which pose health or safety hazards, prevent unauthorized entry, and protect authorized entrants through ventilation, atmospheric testing and monitoring, and availability of emergency equipment.
- Provides OSHA the authority to set standards for exposure to toxic substances in the workplace which most adequately assures that no employee will suffer material impairment of health or functional capacity even if the employee has regular exposure to the hazard dealt with by the standard for the period of his/her working life.
- Requires regulated employers to maintain accurate records of employee exposures to potentially toxic materials which are required to be monitored or measured under OSHA standards.
- Requires regulated employers (agriculture, forestry, and public utilities are among the categories of employers whose workers may be exposed to pesticides on the job) to maintain records of work-related injuries, illnesses, and deaths.
- Requires regulated employers to maintain a respiratory protection program for workers who wear respirators. Includes provision for medical evaluations to be conducted by a physician or other licensed health care professional.

Toxic Substances Control Act (TSCA)

Enacted by Congress in 1976, this law gives EPA the authority to track the 75,000 industrial chemicals currently produced or imported into the United States. TSCA's objective is to allow EPA to regulate new commercial chemicals before they enter the market, to regulate existing chemicals when they pose an unreasonable risk to health or to the environment, and to regulate their distribution and use. Chemicals making claims as a pesticide are regulated under FIFRA and FQPA, not TSCA.

- Establishes an inventory of chemical substances and provides for their review. If a chemical is not already on EPA's inventory of chemical substances, and has not been excluded by TSCA, a premanufacture notice (PMN) must be submitted to EPA before manufacture or import. The PMN must identify the chemical and provide available information on health and environmental effects. If available data are not sufficient to evaluate the chemical's effects, EPA can impose restrictions pending the development of information on its health and environmental effects. EPA can also restrict significant new uses of chemicals based on factors such as the projected volume and use of the chemical.
- Requires manufacturers of regulated chemicals to submit test results to EPA. In general, testing required for substances regulated under TSCA is not as extensive as that required for pesticides under FIFRA and FQPA.

Emergency Planning and Community Right-To-Know Act (EPCRA) (Superfund Amendments and Reauthorization Act, Title III, or SARA Title III)

The objectives of SARA Title III. are to: allow state and local planning for chemical emergencies, provide for notification of emergency releases of chemicals, and address communities' right to know about toxic and hazardous chemicals.

- Excludes proper application of pesticide products as well as handling and storage of those pesticide products by an agricultural producer. Such use and storage is regulated under FIFRA.
- Requires notification of spills or releases of hazardous substances.
- Directs facilities storing hazardous substances to appoint an emergency response coordinator.
- Mandates clean-up of spills and releases, including past disposals.
- Stipulates that all information submitted pursuant to SARA Title III. regulations shall be publicly accessible, unless protected by a trade secret claim.

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