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 Grube, 1999). This figure accounts for about three-quarters of the total used, with the remainder split about evenly between applications by homeowners and professional pest control applicators (Aspelin and Grube, 1999). However, it should be noted that on a per-acre basis, homeowners use many times more pesticide on their lawns and gardens than the amounts applied on agricultural land (Robinson et al, 1994).

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 and carbamate insecticides) is much higher than the older products, making them more hazardous for users to handle. In addition, their increased water solubility raises the likelihood of 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 a larger variety of different products are in use, but in a far smaller volume (ounces per acre, rather than pounds per acre) than in the past. Nevertheless, overall pesticide use (lbs/yr) has steadily increased over the years.

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;
- household pets to control fleas and ticks; and
- livestock to control insects and other pests.

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 section 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. (Aspelin and Grube, 1999). 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. As of the writing of this document, inert ingredients are not required to be identified on the pesticide label, although their percentage must be indicated. EPA is considering changes that would require some or all inert ingredients to be identified on the label.

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 most applications, such as 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 may cause unreasonable adverse effects on humans 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. In order to become certified, applicators must receive instruction in the proper use of RUPs and, in most states, pass a written examination. By federal law, all pesticides not classified as RUP are available for sale to, and use by, anyone without a requirement for special training. However, many states have stricter pesticide laws requiring training and/or certification for anyone who applies pesticides to someone else's property, regardless of whether the product used is classified as RUP.

Pesticide Quick Facts

- There are approximately 4 million members of the agricultural workforce in the U.S. and a million or more pesticide applicators who are at potential risk for pesticide exposure because of mixing or applying pesticides or working in fields where pesticides have been applied. (U.S. EPA, 1992)
- Based on states with required reporting of pesticide-related health concerns, EPA estimates that 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 exposure (e.g., pine oil cleaners, bathroom cleaning products, and cleaning materials for swimming pools). Work-related exposures for structural pest control operators and workers in nurseries, greenhouses, and landscaping are also of concern in the non-agricultural sector. The medical profession uses disinfectants to sanitize and sterilize surfaces and instruments.
- Organophosphate and pyrethroid insecticides are the categories of pesticides most often implicated in acute pesticide-related illnesses reported to poison control centers.
- Chlorination for purposes of purifying water is one of the largest (by tonnage) uses of pesticides.

About three-fourths of U.S. households use pesticides (Aspelin and Grube, 1999). Few homeowners who use pesticides themselves have received any training. Because products can be purchased at grocery stores, hardware stores, and pharmacies, consumers may assume that the products they use themselves do not pose potential hazards to health or the environment. In fact, most products marketed for the homeowner contain the same active and inert ingredients as those for commercial markets, although usually at lower concentrations.

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 higher rate than the label allows. Potential risks can be minimized by choosing alternative measures when feasible and by using pesticides sparingly. When applying pesticides, care should be given to wearing the proper protective gear (as indicated on the label), and applying, storing, and disposing of pesticides properly. Consideration should also be given to the presence of children in the area. Children are more apt to have extended contact with ground level surfaces and may have extended contact with pets. Spot treatments, directed or crack and crevice sprays, baits, gels, and pastes pose less potential for exposure than broadcast treatments.

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.

- Fumigants (pesticides that form poisonous gases when applied) are highly toxic to humans and all other living organisms. Some active ingredients are liquids when packaged under high pressure but change to gases when released. Others are volatile liquids when enclosed in an ordinary container and so are not formulated under pressure. Still others are solids that release gases when applied under conditions of high humidity or in the presence of water vapor. Fumigants can injure workers severely through inhalation and dermal exposure even in a short period of exposure. They require the use of specialized protective equipment, including respirators.

- Aerosols (typically, low percentage of active ingredient sprayed out as a fine mist or fog) are difficult to contain on site and are easily inhaled.

- Dusts (typically, a 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. Dusts are less easily absorbed through the skin but are easily inhaled. Some dusts, such as sulfur, contain high levels of active ingredient. Sulfur is one of the most heavily used pesticides in California and has been responsible for the highest number of pesticide-related illnesses/injuries there.

- 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.

Patterns of Exposure

Three types of exposure patterns are considered here: occupational, incidental, and intentional 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 pesticide residues remaining on the plants, but their jobs may require them to spend more time in treated areas than the applicator.

Since the majority of the pesticide applicator work force is overwhelmingly male, there are few studies of women exposed to pesticides at work. Women who work with pesticides may want to consider switching to other tasks, if possible, at least during the first trimester of pregnancy, or should maximize their use of personal protective clothing.

EPA's Worker Protection Standard is the federal regulation that applies to agricultural pesticide handlers and field workers. It includes requirements for: posted warnings about pesticide applications, use of personal protective equipment (PPE), restrictions on re-entry into treated areas, decontamination, emergency medical assistance, and pesticide safety training.

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 restricted entry interval or REI); and whether training is required for workers and pesticide handlers on farms, forests, greenhouses, and nurseries. As of the writing of this document, the REI applies only to workers, not to the general public. EPA is currently considering instituting separate REIs for others, including, for example, consumers who enter treated "pick-your-own" operations. 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 exposure potential for workers is much greater than for consumers, and the REI established for each type of reentry might differ.

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 typically have the least specialized application equipment, but they usually apply 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.

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, and public buildings; and at recreational areas. National attention is focusing interest on integrated pest management (IPM) strategies rather than relying solely on conventional pesticide treatments in and around schools and public buildings. Long utilized in many agricultural systems, IPM 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. IPM considers aspects such as 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. 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, or not use PPE to minimize exposure.

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 pesti-

cide 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, in areas accessible to children. Children and others have also been injured when empty pesticide containers have been re-used for other purposes, as residues remain in the containers.

Infants, children, the elderly, and those with compromised immune systems are at special risk if overexposed to pesticides. Children incur more risk than adults due to the immature nature of their immune system, larger surface area to body weight ration, higher metabolic rate, different diet patterns and activities, different exposure profiles, and hormonal changes at puberty.

Intentional Exposures

Suicide attempts, primarily through ingestion, have accounted for deaths and serious injuries. A total of 808 cases of suicide attempts involving pesticides were reported to Poison Control Centers in 1995 (Litovitz et al, 1996). Pesticides used in suicide attempts are often those commonly found in homes or on farms.

Pesticides are thought to be a possible choice for terrorists. Even products not considered to be highly acutely toxic could disrupt the infrastructure and/or cause panic if introduced into water sources, sprayed over populated areas, or otherwise misused.

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