Chapter 61

Surveillance of Pesticide-Related Illness and Injury in Humans*

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61.1 INTRODUCTION

A simple concise definition for public health surveillance is "data for action" (Giesecke, 1999). The traditional definition used by the Centers for Disease Control and Prevention (CDC) is the ongoing, systematic collection, analysis, and interpretation of outcome-specific data for use in the planning, implementation, and evaluation of public health practice (Thacker and Berkelman, 1988). There are three broad types of public health surveillance: hazard surveillance, exposure surveillance, and disease surveillance (Figure 61.1). Each of these types of surveillance can be used to generate data that are vital for targeting public health resources to prevent illnesses and injuries.

Acute pesticide illnesses and injuries are preventable. The first step to preventing these illnesses and injuries is to understand the who, when, where, and why of these conditions. Public heath surveillance activities are vital to capturing this information (Stanbury *et al.*, 2008). The most important use of surveillance data is to guide prevention activities, including regulatory, enforcement, consultative, or educational interventions. Surveillance can produce many data products that are useful for directing preventive action, including (1) estimation of the magnitude of the problem, (2) identification of trends in disease occurrence, (3) identification of epidemics or clusters of disease, (4) identification of emerging problems or new populations at risk of disease, and (5) evaluation of the effectiveness of prevention and intervention efforts. Through the dissemination of these data, public health surveillance focuses attention on important health problems.

The toxicity of pesticides continues to raise public concern and is the focus of much media attention. The importance of pesticides to protect the food supply and to control disease vectors is well recognized. However, it is also recognized that there is no perfectly safe form of pest control. Because society allows pesticides to be disseminated into the environment, society also incurs the obligation to track the health effects of pesticides. As such, surveillance of pesticide-related illness and injury continues to be important. Pesticide poisoning surveillance has been endorsed by several organizations, including the American Medical Association (1997), the Council of State and Territorial Epidemiologists (2009), the Pew Environmental Health Commission (2001), the National Institute for Occupational Safety and Health (NIOSH, 2001), and the U.S. Government Accountability Office (2000) (Figure 61.2).

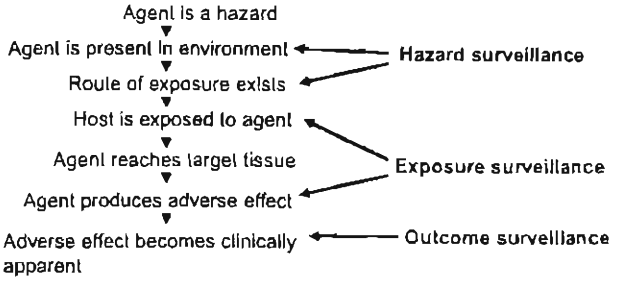


FIGURE 61.1 Three types of public health surveillance.

*The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the National Institute for Occupational Safety and Health or each author's agency.

FIGURE 61.2 A powered air-purifying respirator protects a worker using a thermal fogger in a greenhouse (courtesy of California EPA).

Pesticide poisoning among humans generally occurs either because of lack of compliance with existing pesticide regulations or because existing pesticide regulations are insufficient. The first cause involves cases that are preventable by following the precautionary measures specified on product labels and in governmental pesticide regulations. The appropriate interventions for these cases include enhanced education and enforcement. The second cause arises despite compliance with label instructions and regulatory measures and therefore requires interventions aimed at changing pesticide use practices and/or modifying regulatory measures.

This chapter describes state-based, national, and international surveillance systems for pesticide-related illness and injury. Surveillance systems are the network of individuals and activities that engage in the process of surveillance. There are no national, comprehensive surveillance systems for pesticide-related illness or injury. Therefore, none of the surveillance systems described in this chapter provides a complete understanding of the pesticide-related illness problem. However, each system has strengths and weaknesses, and each system provides data that are useful for directing active intervention.

The focus of this chapter is on surveillance systems that operate in the United States (both state based and national); however, some information is provided on international surveillance efforts. The chapter also describes some of the tools of surveillance (regulations that facilitate surveillance, efforts made to standardize case definitions and variables, and guidelines for evaluating surveillance systems). In addition, the chapter provides a general discussion of the limitations and strengths of surveillance data, with specific reference to the surveillance of pesticide-related illness and injury. Finally, the chapter provides an exploration of the role played by epidemiologic studies in the surveillance of pesticide-related illness and injury.

61.2 SURVEILLANCE SYSTEMS

61.2.1 American Association of Poison Control Centers' National Poison data System

(a) Description

Poison control centers (PCCs) are available free of charge to lay public and health professional callers 24 h a day, 7 days a week. A single toll-free number (800-222-1222) was developed so all callers could access a poison center anywhere in the United States. By calling this toll-free number, the caller is electronically routed to the PCC serving his or her area. In 2007, PCCs managed 11,573 total poison calls a day in the United States, of which 6800 were human exposures cases (this equates to approximately one actual or suspected human exposure case every 12.7 s). This results in approximately 8.1 annual exposures per 1000 population nationwide (Bronstein *et al.*, 2008).

PCCs function primarily to provide poison information, telephone management and consultation, collect pertinent data, and deliver professional and public information. All 61 PCCs in the American Association of Poison Control Centers (AAPCC) participate in the National Poison Data System (NPDS) by providing their poison center call data. This data collection system was previously called the Toxic Exposure Surveillance System and was established in 1983. In 2006, NPDS was developed to create a real-time national poison exposure database and surveillance system. Sixty of the nation's 61 poison centers (all except Puerto Rico) upload case data automatically every 1–60 min (mean time interval was 14 min in 2007), resulting in an almost real-time national exposure data collection and surveillance system (Bronstein *et al.*, 2008). AAPCC was chartered in 1958 as a nonprofit, nongovernmental association to manage poisonings.

TABLE 61.1 Total Call Categories to Poison Control Centers, 2006–2007

Call category	Total	%
Total calls	8,257,436	100.0
Total human exposure cases	4,885,580	59.2
Total animal exposure cases	260,097	3.1
Pharmaceutical exposures[a]	1,987,103	40.7
Non pharmaceutical exposures[a]	2,451,521	50.2
Pesticide exposures	228,628	4.7
Confirmed nonexposure	2477	0.03
Total information cases	3,091,482	37.4
Pesticide information calls	8912	0.2

[a]Single substance exposures only.

PCCs represent an independent member association that works closely with health departments and a variety of governmental agencies, including the Health Resources and Services Administration/Maternal and Child Health Bureau, Food and Drug Administration, U.S. Environmental Protection Agency (EPA), and the CDC (Bronstein *et al.*, 2007).

PCCs receive telephone calls from the public as well as health care professionals. Callers often call to request assistance to manage an exposure to a poison (62.3% of all calls). Another 37.4% of calls concern general information requests that do not involve a victim (e.g., drug interactions, drug identification, toxicity of plants, drug or chemical disposal, or medical information) (Table 61.1).

Among all exposures, the proportion among children younger than 3 years is 38.1%, children aged 3–5 years 13%, children aged 6–12 years 6.3%, teens (aged 13–19 years) 7.0%, and adults (older than 19 years) 34.8%. Home is the most common site of exposure (91.2%), followed by the workplace (2.1%) and school (1.5%) (Bronstein *et al.*, 2007, 2008).

The route of exposure is most commonly by ingestion (77.8%), followed by dermal (7.4%), inhalation (5.7%), and ocular (5.1%). Of human exposures, 83.3% were unintentional, 12.9% were intentional, 2.5% were adverse reactions to products, and 1.2% included other reasons such as malicious intent, product contamination, or drug withdrawal. With advice from the PCC, 72.8% of cases are managed at home and 23.6% of cases are managed in a health care facility (HCF). The remainder (3.6%) are lost to follow-up (Bronstein *et al.*, 2007, 2008).

The age of the patient is associated with the treatment site, which is a surrogate for the severity of the exposure. HCF treatment occurs in 10.6% of exposed children younger than 6 years, 12.6% of exposed children aged 6–12 years, 47.4% of exposed teens (age 13–19 years), and 37.4% of exposed adults (older than 19 years). Young children are less likely to have severe illness because they are usually exposed to small amounts of substances that do not result in toxicity compared to teens and adults, who are more frequently exposed to larger amounts or to more dangerous substances (Bronstein *et al.*, 2007, 2008).

Poison calls are managed by specially trained health care professionals called "specialists in poison information" (SPIs) who are usually clinical pharmacists with a Doctor of Pharmacy (PharmD) degree or registered nurses. When the SPI has worked 2000 h and has managed 2000 human exposure cases, he or she is eligible to sit for the national certification examination given by AAPCC. After passing the certification examination, the SPI becomes a Certified Specialist in Poison Information (CSPI). Some poison centers also utilize adjunct health care professionals (e.g., pharmacy technicians, paramedics, and licensed vocational nurses) called "poison information providers" who manage less serious home cases and work under the overview of CSPIs.

PCC managing directors provide direction, administrative supervision, and clinical education of staff. Most directors are board-certified clinical toxicologists who are Diplomates of the American Board of Applied Toxicology. Medical direction is provided by board-certified physician medical toxicologists who are available on call 24 h a day, 7 days a week. They provide medical oversight for staff and provide direction for the management of dangerous, difficult or unusual cases.

Fifty-eight of the poison control centers (95%) submitting data to NPDS are certified PCCs. AAPCC developed certification criteria to recognize PCCs as qualified to serve their population. To be certified, a PCC must fulfill the following criteria to help ensure the quality of the center and the data (AAPCC, 2005):

1. Provide poison information 24 h a day, 365 days a year to both health professionals and the public.
2. Be readily accessible by telephone from all areas of the region.
3. Maintain comprehensive poison information resources.
4. Maintain written operational guidelines that provide a consistent approach to evaluation and management of toxic exposures.
5. Have a board-certified medical toxicologist on call at all times for medical direction.
6. Have a managing director who provides direct toxicologic supervision of PCC staff, strategic planning, and administrative oversight.
7. Have an SPI on duty at all times. SPIs must complete a training program and be certified.
8. Have an ongoing quality assurance program.
9. Keep standardized records on all cases handled by the center in a form that is acceptable as a medical record.

10. Submit all human exposure data meeting quality requirements and all required data elements to the NPDS. Standard data elements include the time and date of the call, age and sex of the victim, location of victim at the time of exposure (e.g., home and workplace), location of the call (county, zip code, etc.), exposure substance, route of exposure, symptom assessment, source of treatment (e.g., on site or HCF), and an evaluation of medical outcome after case follow-up. Case follow-up generally involves telephone contact with the patient or the relevant health care professional.
11. Tabulate its experience for regional program evaluation and hazard surveillance.
12. Monitor the emergence of poisoning hazards and take action to eliminate poison hazards.
13. Provide information on the management of poisoning to health professionals throughout its region.
14. Provide a variety of public education activities, targeting "at-risk" populations.

Poison center pesticide cases are identified through records of telephone calls from the lay public and health care professionals seeking information on how to manage an exposure to a pesticide.

Poison exposure cases followed to a known outcome are categorized into outcomes of no effect, minor, moderate, major, death, or unrelated, depending on symptoms and severity. Definitions used by the PCCs to categorize medical outcome are summarized as follows (Bronstein *et al.*, 2007, 2008):

No effect: Patient developed no symptoms as a result of the exposure.

Minor: Minimal symptoms that resolved quickly with no residual disability (e.g., mild gastrointestinal symptoms, skin irritation, and drowsiness).

Moderate: Symptoms are more pronounced, prolonged, or more of a systemic nature than minor symptoms, result in no residual disability and are not life-threatening. Usually some treatment is indicated. Examples include corneal abrasions, high fever, disorientation, hypotension that rapidly responds to treatment, and isolated brief seizures.

Major: Symptoms are life-threatening or result in residual disability or disfigurement. Examples include patients who require intubation plus mechanical ventilation and patients who sustain repeated seizures, cardiovascular instability, or coma.

Death: Patient died as a result of the exposure or as a direct complication.

Unrelated: The poison exposure most likely was not responsible for the effects.

PCC SPIs rely on their experience and judgment to determine whether cases have symptoms consistent with the toxicology, dose, and timing of the pesticide exposure. SPIs utilize information in PoisIndex, among other resources, to help them determine if symptoms are related or not. PoisIndex is a computerized database updated quarterly with information on approximately 1 million substances, including prescription, over-the-counter, generic, and foreign pharmaceuticals; street drugs; dietary supplements; cleaning agents; personal care items; household items; plants; insect, snake and animal bites; chemicals; pesticides; arts and crafts products; and industrial products (Klasco, 2009).

Whereas 90.9% of cases involve exposure to a single substance, the remainder involve exposure to more than one substance or to unknown substances, making assessment of symptoms more difficult. Other situations that make assessment of a poison exposure more difficult and complex for PCC staff include the following:

1. The caller does not have the container at the time of the call and believes that the company or manufacturer name is the same as the product name.
2. The caller tries to describe the container over the phone with the belief that the description of the product will properly identify the exact product (e.g., "It's in an orange can about 10 inches tall that you use to kill roaches").
3. The supposed "inert ingredients" (i.e., the ingredients other than the active ingredients) are often not listed on the pesticide product label or in the PoisIndex product information. Not knowing if the pesticide product active ingredient is causing the symptoms rather than an unnamed surfactant, solvent, or petroleum distillate makes treatment decisions more difficult. If simple category information on inert ingredients such as "surfactants" were included on the label, medical treatment of exposures would be much easier.
4. The ongoing problem of placing pesticides in unlabeled food or drink storage containers. If an exposure to the unknown substance occurs in a situation such as this and no label information or other identifying information is available, valuable emergency treatment can be delayed, leading to major health consequences or even death.

Patients treated at home or any other non-health care site are classified as "managed on site." Patients seen in an HCF may be categorized as treated and released or admitted for medical care. "Admitted for medical care" is used when the patient is admitted as an inpatient to receive medical care. Some patients are admitted for further psychiatric evaluation rather than for medical care. For all human exposure cases seen at an HCF, 50.3% are treated and released, 14.9% are admitted to critical care, 8.7% are admitted for noncritical care, 1.9% are admitted for psychiatric evaluation, and 24% are lost to follow-up (Bronstein *et al.*, 2007, 2008).

In 2006, NPDS modified the way in which data are collected and interpreted, so this report uses data only for the

years 2006 and 2007. Beginning in 2006, data were collected only on single substance exposures rather than on multiple substance exposures, resulting in a better correlation among exposure, symptoms, and outcomes.

In 2006, interpretation of death outcomes for poisoning fatality reports was also changed. In the past, some AAPCC death reports included cases such as a patient found dead surrounded by empty containers. No autopsy was performed, the cause of death was not obtained, and yet the case was coded as a fatality related to the products found by the body. In reality, death may or may not have been from exposure to the substances. Beginning in 2006, in an effort to make more evidence-based decisions on fatality cases, each death abstract was peer-reviewed by a team of two independent toxicologists consisting of a medical toxicologist and a clinical toxicologist. Case evidence was reviewed and ranked to determine if the exposure was the undoubted cause of death. Obtaining the medical examiner's reports for each death case was encouraged, and the coroner's results were also reviewed. In addition, a uniform method for collecting information on blood, plasma, serum, and vitreous toxin concentrations along with units and time of collection was also added. Using all the evidence gathered, a decision was made regarding whether the exposure was reasonably responsible or not responsible for the death. Only cases graded with reasonable confidence that the death was related to the exposure were reported as poisoning fatality cases. This resulted in smaller numbers of fatality cases being reported to the NPDS, but the cases were more authentically related to the exposure (Bronstein *et al.*, 2007, 2008).

PCCs were able to determine the medical outcome for 44.7% of all reported exposures. With outcome data, several measures of severity were used in this review of PCC data, including the percentage of cases reporting pesticide-related symptoms or clinical effects; the percentage of cases that had a reported medical outcome, ranging from minor to death; and the percentage of pesticide exposure cases that were seen in an HCF. However, in many cases, patients presented to an HCF even though they did not have or never developed clinical symptoms. Fear and anxiety about the perceived risk of exposure may have played a role in the desire to seek medical attention.

(b) Data Source

All 61 of the nation's PCCs participate in NPDS. Sixty of the 61 PCCs upload poison case data to NPDS automatically at a mean of every 14 min, resulting in near real-time surveillance and data collection. (Note that Puerto Rico did not have automatic case upload in 2006 and 2007.)

(c) Target Population

The entire U.S. population including all 50 states, the District of Columbia, American Samoa, Micronesia, Guam, Puerto Rico, and the American Virgin Islands is served by the PCCs included in NPDS. Because reporting of poison exposures is not mandatory, it must be kept in mind that PCCs do not collect all poison cases within their catchment areas. Of the 4 million poisoning cases estimated to occur in the United States annually (involving all poisons and not just pesticides), approximately 57% (2.27 million) are captured by the NPDS (Institute of Medicine, 2004).

(d) Period of Data Collection

All NPDS data for the years 2006 and 2007 were utilized.

(e) Periodicity of Reports

Data are available by calendar year. The NPDS annual report, which includes information on all types of poison exposures, is published annually in the December issue of *Clinical Toxicology*. Additional NPDS data can be purchased from the AAPCC (see www.aapcc.org).

(f) Results

As described previously, PCCs are also used as a resource on a variety of pesticide-related information questions. Table 61.2 provides the types of pesticide information calls received by PCCs in 2006 and 2007. The current review of pesticide exposure cases is based on 228,628 records of pesticide-related exposures reported to PCCs participating in NPDS during 2006 and 2007 (see Table 61.1). Pesticides accounted for 4.7% of all human exposures reported to PCCs. In contrast, for single substance exposures, 40.7% of all exposures were due to pharmaceuticals and 50.2% were due to exposure to nonpharmaceuticals. The leading cause of pesticide exposures was from insecticides (45.0%). Among insecticides, pyrethrins were the most frequently involved (10%) (Table 61.3).

Although attempted suicide cases comprised 8.4% of all calls to PCCs, pesticides are used in only 1.7% of intentional poison exposures. Whereas pesticides ranked as the eighth most frequent category of exposures in both adult and pediatric populations, pesticides are not listed in the top 20 categories most frequently associated with the largest number of fatalities. The 10 leading categories of attempted suicide, as captured by PCCs, are sedative hypnotics/antipsychotics, opioids, antidepressants, acetaminophen combination products, cardiovascular drugs, stimulant street drugs, alcohols, acetaminophen as a sole ingredient, anticonvulsants, and fumes/gases/vapors such as carbon monoxide (Bronstein *et al.*, 2007, 2008).

A primary factor in determining risk to pesticides is the age of the patient (Table 61.4). Children younger than 6 years accounted for 87.90% of the anticoagulant rodenticide exposures, 83.8% of boric acid insecticide exposures, 65.5% of phenol-containing disinfectant exposures, and 51.9% of all disinfectant exposures. Unlike the other types of pesticides, rodenticides and roach baits are used almost exclusively as poison baits placed on the floor where

TABLE 61.2 Information Calls Made to Poison Control Centers Explicitly or Implicitly Related to Pesticides, 2006–2007

Type of poison center information calls explicitly related to pesticides	No.	%
General questions about pesticide applications made by a professional pest control officer	1648	18.5
General pesticide information (other)	6505	73.0
Immediate referral to pesticide hotline because of suspected poisoning	759	8.5
Total	8912	100.0
Other types of poison center information calls that may apply to pesticides		
Safe disposal of chemicals	3979	20.0
Safe handling of workplace chemicals	298	1.5
Safe use of household products	8234	41.4
Routine toxicity monitoring	148	0.7
Clarification of media reports of environmental contamination	107	0.5
Water purity/contamination	2240	11.3
Potential toxicity of chemicals in the environment	3386	17.0%
General questions about contamination of air and/or soil	1518	7.6
Total	**19,910**	**100.0**

young children have access to them. Greater use of child-resistant packaging would substantially reduce the number of pediatric cases. This is particularly true for disinfectants and other products stored in bottles. For baits, tamper-resistant bait stations can be used to reduce exposures to children.

Table 61.5 provides a comparison of substance exposures by age category. For DEET-containing insect repellents, 65.4% of cases involved children younger than 6 years. Many of these cases most likely occurred when the product was applied on them, resulting in the child sampling the bottle contents, licking exposed skin areas where the insecticide was applied, or rubbing exposed hands into his or her eyes. By contrast, only 14.1% of the fumigant cases and 21.7% of the fungicides involved children younger than 6 years. These pesticides are more likely to be used and stored outside or where young children have little access. Insecticide exposures were involved in 38.2% of cases in children younger than 6 years.

TABLE 61.3 Pesticide Exposures by Pesticide Functional and Chemical Class, 2006–2007

Pesticide type	Total	%
Disinfectants		
Hypochlorite	22,013	9.6
Phenol	8579	3.8
Pine oil	5029	2.2
Other	11,841	5.2
Total	47,462	20.8
Fumigants		
Sulfuryl fluoride	424	0.2
Other	340	1.5
Total	764	0.3
Fungicides	2260	1.0
Herbicides		
Chlorphenoxy compounds	4039	1.8
Glyphosate	8319	3.6
Other	4850	2.1
Total	17,208	7.5
Insecticides		
Boric acid/borates	8394	3.7
Carbamates	4898	2.1
Chlorinated hydrocarbons	1042	0.5
Organophosphates	7680	3.4
Pyrethrins	10,235	4.5
Others and combinations	70,577	30.0
Total	102,826	45.0
Repellants		
Insect, DEET	15,076	6.6
Moth	7706	3.4
Other	4452	1.9
Total	27,234	11.9
Rodenticides		
Anticoagulant	25,140	11.0
Other	5734	2.5
Total	30,874	13.5
Total	**228,628**	**100**

TABLE 61.4 Pesticide Exposures by Pesticide Functional and Chemical Class and Patient Age, 2006–2007

		<6 years		6–19 years		>19 years	
Pesticide type	Total	No.	%	No.	%	No.	%
Disinfectants							
Hypochlorite	22,013	8524	38.7	2454	11.1	8683	39.4
Phenol	8579	5623	65.5	948	11.1	1569	18.3
Pine oil	5029	2926	58.2	441	8.8	1338	26.6
Other	11,841	7567	63.9	1151	9.7	2494	21.1
Total	47,462	24,640	51.9	4994	10.5	14,084	29.7
Fumigants							
Sulfuryl fluoride	424	64	15.1	73	17.2	238	56.1
Other	340	44	12.9	28	8.2	201	59.1
Total	764	108	14.1	101	13.2	439	57.5
Fungicides	2260	490	21.7	167	7.4	1211	53.6
Herbicides							
Chlorphenoxy compounds	4039	1173	29	353	8.7	2078	51.4
Glyphosate	8319	2490	29.9	598	7.2	4601	55.3
Other	4850	1168	24.1	406	8.4	2681	55.3
Total	17,208	4831	28.1	1357	7.9	9360	54.4
Insecticides							
Boric acid/borates	8394	7035	83.8	310	3.7	830	9.9
Carbamates	4898	1900	38.8	446	9.1	1977	40.4
Chlorinated hydrocarbons	1042	418	40.1	132	12.7	382	36.7
Organophosphates	7680	2105	27.4	820	10.7	3840	50
Pyrethrins	10,235	3861	37.7	1221	11.9	4136	40.4
Others and combinations	70,577	23,962	34	6512	9.2	32,299	45.8
Total	102,826	39,281	38.2	9441	9.2	43,464	42.3
Repellants							
Insect, DEET	15,076	9861	65.4	2651	17.6	1997	13.2
Moth	7706	4764	61.8	486	6.3	1729	22.4
Other	4452	3056	68.6	475	10.7	739	16.6
Total	27,234	17,681	64.9	3612	13.3	4465	16.4
Rodenticides							
Anticoagulant	25,140	22,106	87.9	723	2.9	1840	7.3
Other	5734	3812	66.5	363	6.3	1128	19.7
Total	30,874	25,918	83.9	1086	3.5	2968	9.6
Total	228,628	112,778	49.3	20,758	9.1	75,991	33.2

TABLE 61.5 Top Five Pesticide Category Exposures by Age Group, as a Percentage of All Reported Pesticide Exposures, 2006–2007

Ranking	<6 years		6–19 years		>19 years	
	Substance	%	Substance	%	Substance	%
1	Anticoagulant rodenticides	9.006	Pyrethrin/pyrethroid insecticides	2.061	Pyrethrin/pyrethroid insecticides	9.960
2	Pyrethrin/pyrethroid insecticides	6.187	DEET insect repellants	1.080	Other insecticides[a]	4.205
3	Other insecticides[a]	4.839	Other insecticides[a]	1.016	Hypochlorite disinfectants	3.537
4	DEET insect repellants	4.017	Hypochlorite disinfectants	1.000	Glyphosate herbicides	1.874
5	Other disinfectants[b]	4.008	Other disinfectants[b]	0.644	Other herbicides[c]	1.092

[a] *"Other insecticides" include insecticides other than boric acid/borates, carbamates, chlorinated hydrocarbons, organophosphates, and pyrethrins/pyrethoids.*

[b] *"Other disinfectants" include disinfectants other than hypochlorite, phenol, and pine oil.*

[c] *"Other herbicides" include herbicides other than chlorophenoxy compounds and glyphosate.*

Table 61.6 presents information on cases that were followed and determined to have symptoms related to their exposure. (Note that only 44.7% of cases receive follow-up to determine a final outcome.) Exposures that are expected to have no effect or minor effects, in the judgment of the SPI, often receive no follow-up and account for 46.8% of all exposures reported to the PCC. An additional 3.6% of all exposures are lost to follow-up. The remaining 2.5% of exposures involve individuals with health effects judged to be unrelated to their exposure.

Among cases that received follow-up to determine medical outcome, SPIs determined that 20.7% of all pesticide exposure cases developed exposure-related symptoms. The percentage of exposures with symptoms varied with pesticide class. Symptoms developed in only 1.5% for anticoagulant rodenticide exposures, 3.8% for boric acid insecticides, up to 32.9% for other fumigants, and 32.8% for DEET-containing repellants.

The low percentage of symptomatic anticoagulant rodenticide exposures is likely related to the high percentage of exposures that occur among children younger than 6 years who ingest small "taste" amounts. Parents of these children contact a poison center before symptoms have developed. The overwhelming majority of exposures are to anticoagulant rodenticides, which have very low toxicity to humans unless ingested in high quantity or repeatedly over a short period of time.

Major outcomes combined with fatal outcomes were compared to all symptomatic pesticide exposures (Table 61.7). Exposure to rodenticides of all types ranked highest in severity, with 6.3% of cases in the major combined with fatal outcomes. This severe outcome is undoubtedly the result of intentional self-harm use of these products by teens and adults. Tied for first place was exposure to fumigants other than sulfuryl fluoride, also at 6.3%. Organophosphate insecticides at 3.5% closely followed by carbamate insecticides at 3.4% ranked second and third, respectively, for severe outcomes. Some of the more toxic organophosphate and chlorinated hydrocarbon insecticides have been removed from the market. This has no doubt contributed to the decreased incidence in severe pesticide poisoning. Overall, only 0.8% of all pesticide exposure cases involved a severe outcome, but that still represents 365 patient cases during a 2-year period.

(g) Discussion

The NPDS data system is an important source of surveillance data of pesticide-related illness and injury. The system has several strengths. Among these are the large number of cases that are reported with approximately half (44.7%) of the reported exposures receiving follow-up. Follow-up with one call-back occurs in 50% of these cases, and multiple (range, 2–135) follow-up calls are made in the other 50% of cases. With this follow-up, the severity of the medical outcome is determined (Bronstein *et al.*, 2007, 2008).

The NPDS system also has limitations. PCCs do not collect all poison cases because reporting of poison cases is not mandatory. Many poisoning cases seen in emergency rooms, clinics, or by private physicians do not result in calls to a PCC. NPDS data represent approximately 57% of poisonings according to estimates by the Institute of Medicine. As a result, any study using PCCs as a source for poisoning cases can only be judged representative of the universe of exposures reported to PCCs and not the entire universe of all poison exposures. PCC data are a simple form of a case series and therefore not appropriate for complicated statistical analysis. However, given that the entire population of the United States and its territories is served by PCCs participating in NPDS and the large number

TABLE 61.6 Pesticide Category and Patient Outcomes by Severity

Pesticide category	Total exposures	Treated in an HCF	Minor	Moderate	Major	Death
Disinfectants						
Hypochlorite	22,013	4695	5538	915	27	1
Phenol	8579	882	1789	158	8	0
Pine oil	5029	829	1176	100	8	0
Other	11,841	1444	2548	216	13	1
Total	47,462	7850	11,051	1389	56	2
Fumigants						
Sulfuryl fluoride	424	70	53	9	1	0
Other	340	153	75	30	5	2
Total	764	223	128	39	6	2
Fungicides	2260	445	437	76	2	0
Herbicides						
Chlorphenoxy compounds	4039	708	809	134	5	0
Glyphosate	8319	1381	2172	179	12	6
Other	4850	1030	1020	226	13	3
Total	17,208	3119	4001	539	30	9
Insecticides						
Boric acid/borates	8394	521	291	29	1	0
Carbamates	4898	958	633	162	25	3
Chlorinated hydrocarbons	1042	306	155	39	4	0
Organophosphates	7680	1967	1634	361	62	11
Pyrethrins	10,235	1588	1995	351	5	1
Others and combinations	70,577	10,898	14,117	2154	78	3
Total	102,826	16,238	18,825	3096	175	18
Repellants						
Insect, DEET	15,076	1280	4667	269	9	0
Moth	7706	1383	546	87	5	0
Other	4452	296	956	54	2	1
Total	27,234	2959	6169	410	16	1
Rodenticides						
Anticoagulant	25,140	7140	246	118	23	1
Other	5734	1855	243	110	21	3
Total	30,874	8995	489	228	44	4
Total	228,628	42,262	41,099	5782	329	36

TABLE 61.7 Comparison of Patients with Severe Symptoms (Major Outcome Combined with Deaths) to All Symptomatic Patients, 2006–2007

Pesticide category	Total exposures	Total symptomatic cases	Total cases with major severity or death	% of cases with major severity or death
Disinfectants				
Hypochlorite	22,013	6481	28	0.4
Phenol	8579	1955	8	0.4
Pine oil	5029	1284	8	0.6
Other	11,841	2778	14	0.5
Total	47,462	12,498	58	0.5
Fumigants				
Sulfuryl fluoride	424	63	1	1.6
Other	340	112	7	6.3
Total	764	175	8	4.6
Fungicides	2260	515	2	0.4
Herbicides				
Chlorphenoxy compounds	4039	948	5	0.5
Glyphosate	8319	2369	18	0.8
Other	4850	1262	16	1.3
Total	17,208	4579	39	0.9
Insecticides				
Boric acid/borates	8394	321	1	0.3
Carbamates	4898	823	28	3.4
Chlorinated hydrocarbons	1042	198	4	2
Organophosphates	7680	2068	73	3.5
Pyrethrins	10,235	2352	6	0.3
Others and combinations	70,577	16,352	81	0.5
Total	102,826	22,114	193	0.9
Repellants				
Insect, DEET	15,076	4945	9	0.2
Moth	7706	638	5	0.8
Other	4452	1013	3	0.3
Total	27,234	6596	17	0.3
Rodenticides				
Anticoagulant	25,140	388	24	6.2
Other	5734	377	24	6.4
Total	30,874	765	48	6.3
Total	**228,628**	**47,246**	**365**	**0.8**

of poison exposures, PCC data are likely to be helpful for identifying exposure situations that should be targeted for risk mitigation (Institute of Medicine, 2004).

Misclassification may occur when symptoms are self-reported over the phone and are not confirmed by a physician or by laboratory tests. PCC data reflect only what is reported by the lay public or health professional when the PCC is called. Information may be incomplete because it may include what the caller thought was important but may leave out important details. Although 15.5% of calls to PCCs are made by health care professionals, the majority are calls made by the victim or their relative. The PCC SPI must rely on his or her experience and judgment to determine which cases have symptoms consistent with the toxic substance, dose, and timing of the exposure. When health effects are judged to be unrelated to the exposure, evidence should support this determination and should be documented in the PCC case record. Although some misclassification can be expected to occur, it is assumed to be nondifferential across pesticides. That is, there is no reason to believe that SPIs are likely to misclassify one pesticide more or less than another.

Although reports in NPDS are labeled "poison exposures," many of the cases in the database never develop health effects as a result of the exposure. Several potential explanations exist for the lack of health effects in these cases, include the following: Advice provided by the PCC led to prompt treatment (e.g., removing the toxic substance from the skin, rapidly removing the patient from a spray area, and irrigating the eyes thoroughly), the exposure agent was relatively nontoxic, the exposure dose was not great enough to produce toxicity, and the exposure was suspected but actually never occurred (cases coded as "confirmed nonexposures" in which there is sufficient evidence that an exposure never occurred are removed from NPDS). Tracking asymptomatic exposure cases can be useful because asymptomatic cases can be an indicator of the number of pesticide exposures usually occurring at home that are not reported elsewhere.

Limitations involving some severity measures used in this review may be present. When using data obtained from the public in circumstances they consider to be an emergency, inaccuracy is inevitable. A misperception concerning the danger or risk of certain types of products rather than the actual risks may exist. For example, both the public and some health care professionals may perceive ingestion of "rat poison" as more dangerous than ingestion of other types of pesticides. As a result, such cases are more likely to be seen in a health care facility even though the overwhelming majority of cases involve minor exposures to anticoagulants (e.g., just a taste) that pose little risk.

Of pesticide exposures, 49.3% occur in children younger than 6 years. There is a strong possibility that parents may panic when their child ingests a substance called "rat poison," "ant killer," or "roach killer." Parents may take the child to the emergency room immediately without calling for help. Decisions about which cases become hospitalized may be due to inaccurate perceptions of risk and differences in the health care professional's experience.

Obtaining medical care by patients is affected by availability and extent of health insurance coverage or workers' compensation. With PCC advice, triage of patients to the appropriate treatment site results in significant savings in health care costs. PCCs manage 72.8% of cases at home, and this can prevent unnecessary HCF visits. One study showed that for every $1 spent by the poison center, $7 in unneeded health care is saved (Miller and Lestina, 1997).

For those with pesticide exposures, Table 61.8 compares the incidence of patients presenting to an HCF with the incidence of patients who develop symptoms. Overall, 18.5% of pesticide-exposed patients present to a HCF and 20.7% develop symptoms. Exposures to rodenticides result in 29.1% of patients presenting to an HCF but only 2.5% actually develop symptoms, contrasting with 8.5% of patients who present to a HCF with exposures to DEET repellants, while 32.8% develop symptoms. For pesticide-exposure cases called to PCCs, more patients are kept at home than are seen in an HCF.

(h) Syndromic Surveillance

The initial purpose of NPDS was poison center data collection. However, it soon became clear that NPDS, with its almost real-time data collection (PCC cases are uploaded a mean of every 14 min), was important as a public health response network. The CDC and AAPCC are working together to develop a true national poison center data system. Incoming data are continually monitored for any anomalous signal detection. If detected, the signal alerts a member of the AAPCC NPDS surveillance team. If the detected signal is significant, the surveillance team member can contact local PCCs. NPDS can also generate notifications or alerts on items of public health interest, such as adverse reactions, product recalls, or contaminated food. Notifications and alerts on public health issues are also sent to the National Center for Environmental Health at the CDC (Bronstein *et al.*, 2007, 2008).

From September 2006 through 2008, more than 100,000 anomalies were detected. In 2007, there were 352 surveillance definitions continuously running to monitor NPDS data by case anomaly definition and clinical effects (e.g., multiple victims exposed and food poisoning, nerve agents). Surveillance enhancement and software improvements have allowed the addition of case drill-down using GIS (geographic information system). Although PCC data have not identified any index cases, close work with public health agencies shows promise as part of an early detection program. More extensive partnerships with governmental agencies for surveillance purposes are anticipated in the near future. However, as local poison center funding disappears, the major roadblock will be finding the funding (Bronstein *et al.*, 2008).

TABLE 61.8 Number of Patients Treated in a Health Care Facility Compared to the Number of Patients with Symptoms

Pesticide category	Total exposures	Patients treated in an HCF		Symptomatic patients	
		No.	%	No.	%
Disinfectants					
Hypochlorite	22,013	4695	21.3	6481	29.4
Phenol	8579	882	10.3	1955	22.8
Pine oil	5029	829	16.5	1284	25.5
Other	11,841	1444	12.2	2778	23.5
Total	47,462	7850	16.5	12,498	26.3
Fumigants					
Sulfuryl fluoride	424	70	16.5	63	14.9
Other	340	153	45	112	32.9
Total	764	223	29.2	175	22.9
Fungicides	2260	445	19.7	515	22.8
Herbicides					
Chlorphenoxy compounds	4039	708	17.5	948	23.5
Glyphosate	8319	1381	16.6	2369	28.5
Other	4850	1030	21.2	1262	26
Total	17,208	3119	18.1	4579	26.6
Insecticides					
Boric acid/borates	8394	521	6.2	321	3.8
Carbamates	4898	958	19.6	823	16.8
Chlorinated hydrocarbons	1042	306	29.4	198	19
Organophosphates	7680	1967	25.6	2068	26.9
Pyrethrins	10,235	1588	15.5	2352	23
Others and combinations	70,577	10,898	15.4	16,352	23.2
Total	102,826	16,238	15.8	22,114	21.5
Repellants					
Insect, DEET	15,076	1280	8.5	4945	32.8
Moth	7706	1383	17.9	638	8.3
Other	4452	296	6.6	1013	22.8
Total	27,234	2959	10.9	6596	24.2
Rodenticides					
Anticoagulant	25,140	7140	28.4	388	1.5
Other	5734	1855	32.4	377	6.6
Total	30,874	8995	29.1	765	2.5
Total	**228,628**	**42,262**	**18.5**	**47,246**	**20.7**

61.2.2 State-based Surveillance Systems

(a) Description

Thirty states in the United States require some form of physician, laboratory, or hospital reporting of pesticide-related illness. These states are listed in Table 61.9 along with information on the specifics of the reporting rule. Only 12 states (Arizona, California, Florida, Iowa, Louisiana, Michigan, New Mexico, New York, North Carolina, Oregon, Texas, and Washington) routinely conduct more comprehensive case investigation and surveillance activities. In response to both public concern and the successes achieved by the 12 states currently conducting surveillance, other states are considering initiating pesticide poisoning surveillance activities.

Before 1998, the state-based pesticide poisoning surveillance systems used a variety of methods for collecting and categorizing data that did not permit the routine pooling and analysis of multistate data. Recognizing the importance of systematic surveillance efforts, NIOSH, with funding assistance from the U.S. EPA, led efforts to standardize pesticide poisoning surveillance. A collaboration involving experts from federal agencies (NIOSH, U.S. EPA, and National Center for Environmental Health), nonfederal agencies (Council of State and Territorial Epidemiologists and Association of Occupational and Environmental Clinics), and state health departments or other state designees developed a standardized set of variables for pesticide-related illness and injury surveillance. This standardized set of variables, including a standardized case definition (described elsewhere in this chapter), was finalized in 1998 and is used by the 12 states mentioned previously.

The large number of pesticide products on the market and difficulties in obtaining case reports make the pooling of all available data particularly desirable. Having standardized variables and a standardized case definition facilitates the aggregation of these data. The aggregated data have proven useful to regulatory agencies, public health policymakers, researchers, worker education programs, the public, and the medical community.

TABLE 61.9 Pesticide-Related Illness Mandated Reporting Requirements and Entities by State[a]

State	Pesticide reporting requirement[b]	Entities mandated to report				
		Physician	Hospital	Laboratory	Poison control center	Other health care professional
Alaska	ANY OCC DZ	X				
Arizona	ANY PEST	X			X	X
Arkansas	ANY PEST	X	X			
California	ANY PEST	X				X
Florida	ANY PEST	X	X	X		X
Hawaii	ANY PEST	X		X		
Illinois	ANY OCC DZ	X	X	X		
Iowa	ANY PEST	X	X	X	X	X
Louisiana	ANY PEST	X	X	X		
Maine	ANY OCC DZ	X	X			
Maryland	ANY PEST	X	X	X		
Massachusetts	OCC PEST	X	X			
Michigan	ANY OCC DZ	X	X	X		
Mississippi	ANY PEST	X	X	X		X
Missouri	ANY PEST	X	X	X		X
Nebraska	ANY PEST	X	X	X		

(Continued)

TABLE 61.9 (Continued)

State	Pesticide reporting requirement[b]	Entities mandated to report				
		Physician	Hospital	Laboratory	Poison control center	Other health care professional
New Hampshire	ANY OCC DZ	X				
New Jersey	ANY PEST	X	X			
New Mexico	OCC PEST	X	X	X		
New York	ANY PEST	X	X	X		
North Carolina	ANY PEST	X				
Ohio	OCC PEST	X				
Oregon	ANY PEST	X	X	X		
South Carolina	ANY PEST	X	X	X		
Texas	OCC PEST	X	X	X		
Utah	ANY TOXIN	X	X	X		X
Virginia	ANY PEST	X	X	X		
Washington	ANY PEST	X				
Wisconsin	OCC PEST	X	X			
Wyoming	ANY TOXIN	X	X	X		

Sources of data: Calvert et al. (2001); Internet search; personal communication with Erin Simms, Council of State and Territorial Epidemiologists; and e-mails and calls to selected state agencies to clarify inconsistencies.

[a]*This table does not include states with only voluntary pesticide reporting requirements (Idaho, Illinois, North Dakota, South Dakota, and Vermont).*

[b]*ANY PEST, reporting of any pesticide-related illness (whether occupational or nonoccupational) is mandated; OCC PEST, only reporting of occupational pesticide-related illness is mandated (there are no requirements for reporting poisoning from nonoccupational toxic exposures); ANY OCC DZ, reporting of any occupational disease is mandated (there are no specific requirements for pesticide-related illness reporting, nor are there requirements for reporting poisoning from nonoccupational toxic exposures); ANY TOXIN, reporting of any poisoning from toxic exposures is mandated (there are no specific requirements for pesticide-related illness reporting); OCC TOXIN, reporting of any poisoning from occupational toxic exposures is mandated (there are no specific requirements for pesticide-related illness reporting, nor are there requirements for reporting poisoning from nonoccupational toxic exposures).*

This section briefly describes the surveillance systems in the 12 states mentioned previously. Collectively, these states are referred to as the Sentinel Event Notification System for Occupational Risk (SENSOR)-Pesticides program. The SENSOR-Pesticides states have much in common and are not described separately in detail.

However, there are two pesticide poisoning surveillance programs in California. One is maintained by the California Department of Pesticide Regulation (DPR) and the other by the California Department of Public Health (CDPH). The surveillance system maintained by DPR is described in a separate section because it uses a slightly different case definition and variables. The DPR system is also the largest system (both in poisoning cases annually identified and in staffing levels) and has been in existence longer than any other surveillance system with the possible exception of Washington State. The surveillance system maintained by CDPH participates in the SENSOR-Pesticides program and is similar to the other surveillance systems described in this section. However, unlike the other SENSOR-Pesticides systems, the CDPH surveillance system tracks occupational pesticide-related illness and injury only.

The state-based surveillance programs use multiple sources for case ascertainment (see Data Source), and active case follow-up is performed either directly by the surveillance system or conducted by partner state agencies (e.g., the state agriculture department). Several of these state systems originally included a system of sentinel health care professionals who were contacted on a regular basis. This approach was labor-intensive, did not yield many cases, and was discontinued (Schnitzer and Shannon, 1999).

Once a report is received, participating SENSOR-Pesticides states review the information available in the report to determine whether the subject was symptomatic and whether the involved chemical was a pesticide. If so, attempts are made to interview the poisoned subject or his or her proxy to obtain details on the poisoning event. If the subject sought health care, a request is made for relevant medical records. The program may also interview other knowledgeable parties, including the supervisor of the exposed person, the applicator, and witnesses. The information collected by the state agencies in a standardized manner includes date of illness, information on the ill individual (gender, race, age, signs, and symptoms, industry, and occupation), whether the illness occurred as a result of workplace exposures, identification of the pesticide(s) that produced the illness, activity of the individual when exposed, type of exposure (e.g., drift, direct spray, indoor air exposure, or exposure to a spill or leaking container), biological monitoring information (i.e., cholinesterase testing and results and whether other biological testing was performed), factors that contributed to exposure (e.g., lack of notification of pesticide application, early re-entry into a treated area, and equipment failure), and use of personal protective equipment (PPE).

All states that participate in the SENSOR-Pesticides program receive funding support from their state. State funding can come from one or more of the following sources: general funds, licensing fees, or pesticide product registration fees. In addition, seven SENSOR-Pesticides states are partially funded by NIOSH and the U.S. EPA through the SENSOR-Pesticides program. Besides collecting information on each suspected case of pesticide poisoning, these SENSOR-Pesticides surveillance systems perform in-depth investigations for cases that meet priority criteria, identify trends and emerging pesticide problems, prepare reports of investigations and other program activities, and develop interventions aimed at particular industries or hazards. The state-based SENSOR-Pesticides surveillance programs do not have regulatory authority.

In addition to providing funding to some SENSOR-Pesticides states, NIOSH plays several other roles in the SENSOR-Pesticides program. NIOSH provides advice and guidance to states in developing and maintaining their surveillance system. To foster communication with participating states, NIOSH maintains a listserv and website for the program. NIOSH participates in the SENSOR-Pesticides coding committee, which also includes representatives from some SENSOR-Pesticides states. The purpose of this committee is to identify and recommend changes to the standardized variables used by the SENSOR-Pesticides program. NIOSH creates and maintains a national aggregated database of pesticide poisoning cases identified by states participating in the SENOR-Pesticides program. NIOSH also prepares and publishes manuscripts in *Mortality and Morbidity Weekly Report* and peer-reviewed journals. SENSOR-Pesticides state partners rely on NIOSH to produce these papers because the states often do not have the time or expertise for such efforts.

(b) Case Definition

Beginning with cases identified and exposed to pesticides in 1998 or later, the SENSOR-Pesticides program began using the National Public Health Surveillance System case definition and classification scheme to evaluate reports. This case definition is described later (CDC, 2001a). Briefly, information in three areas is required: pesticide exposure, health effects, and toxicological evidence supporting an association between exposure and effect. A case of pesticide-related illness or injury is classified into one of the following categories: definite, probable, possible, or suspicious. The specific classification category applied to a given case depends on the certainty of exposure, whether health effects consisted of signs observed by a health care professional versus symptoms reported by the poisoned subject, and the extent to which the health effects were consistent with the known toxicology of the pesticide product. Illnesses associated with intentional (e.g., suicidal and malicious intent) exposures were excluded from the findings presented here. Reports can also be classified into one of four other categories: unlikely case (untenable exposure–health effect relationship), insufficient information, unrelated (illness determined to be caused by a condition other than pesticide exposure), and asymptomatic. Reports classified into one of these four categories are not considered cases of pesticide-related illness or injury.

Illness severity is also assigned to all cases using standardized criteria that are based on signs and symptoms, medical care received, and lost time from work (CDC, 2001b). *Low severity illness/injury* consists of illnesses and injuries that generally resolve without treatment and where minimal time (<3 days) is lost from work. Such cases typically manifest as eye, skin, and/or upper respiratory irritation. *Moderate severity illness/injury* consists of non-life-threatening health effects that are generally systemic and require medical treatment. No residual disability is detected, and time lost from work is less than 6 days. *High severity illness/injury* consists of life-threatening health effects that usually require hospitalization, involve substantial time lost from work (>5 days), and may result in permanent impairment or disability. *Death* pertains to fatalities resulting from exposure to one or more pesticides.

(c) Data Source

All of these surveillance systems require reporting of pesticide-related illness and injury cases from physicians (see Table 61.9). However, relatively few cases are directly reported by physicians. When SENSOR was originally conceived, cases were to be reported to state

health departments by a targeted group of health care professionals, or sentinel providers (Baker, 1989). However, this concept of SENSOR was abandoned because of the time and expense needed to periodically remind clinicians to report cases (Levy *et al.*, 1992; Schnitzer and Shannon, 1999). The principal source of case reports varies across states but is generally one of the following: workers' compensation claims, poison control centers, and state agencies with jurisdiction over pesticide use (e.g., state agricultural departments). States also routinely review other data sources to identify additional potential cases and to evaluate the completeness of reporting. Other sources of case reports include emergency medical services, medical laboratories, hospital emergency rooms, hospital discharge data, clinics, Migrant Legal Aid, selected community contacts, state structural pest control boards, and death certificates. Most states accept reports from sources other than those required to report through regulation. Some states also accept self-reports as a trigger for investigation.

Both Oregon and Washington maintain interagency boards that are required to coordinate the investigation of reported adverse impacts from pesticides, review incidents, and develop strategies to prevent exposures. The interagency board in Oregon is called the Pesticide Analytical and Response Center (PARC), and the Washington board is called the Pesticide Incident Reporting and Tracking Review Panel (PIRT) (Barnett and Calvert, 2005). Both interagency boards are composed of representatives from agencies with jurisdiction over pesticides, health, and the environment. In addition, these interagency boards include a state poison control center representative and an appointed general public member. PIRT also includes a practicing toxicologist and representation from the state universities. The state universities serve as consultants to the PARC board but are not members.

(d) Target Population

These systems strive to capture any pesticide-related acute illness or injury occurring in the state population. The systems capture illness and injuries resulting from both occupational and nonoccupational exposures, with the exception of the CDPH. In contrast to the DPR, which captures both occupational and nonoccupational cases, CDPH captures occupational cases only.

(e) Period of Time of Data Collection

As explained previously, the SENSOR-Pesticides standardized case definition and standardized variables were finalized in 1998. This permitted the creation of a national aggregated data set beginning in that year. The national aggregated data set includes data from states participating in the SENSOR-Pesticides program (Figure 61.3).

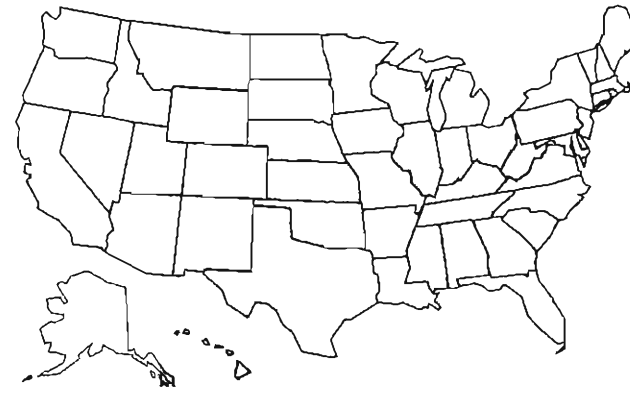


FIGURE 61.3 States that participated in the SENSOR-Pesticides program in 2009 (in white, $n = 12$).

However, in some states, the commencement of acute pesticide-related illness and injury surveillance occurred before 1998. Of the SENSOR-Pesticides states, Washington has the oldest system, having been established in the early 1970s (note that the DPR also had a surveillance system and a reporting law established in the early 1970s). However, Washington did not have an acute pesticide poisoning reporting requirement until 1989. Washington surveillance data are considered complete beginning with calendar year 1991. Of the SENSOR-Pesticides states (excluding California), Texas has the oldest acute pesticide poisoning reporting rule, which was enacted in 1986, and surveillance data are considered complete beginning with calendar year 1988. Oregon has required health care providers to report pesticide poisoning since 1987, and surveillance data are considered complete beginning with calendar year 1988. In Arizona, although the reporting rule went into effect in 1987, surveillance data are considered complete beginning with the calendar year 1992. Likewise, in Florida, the reporting rule went into effect in 1987; however, reporting had been limited until the more comprehensive surveillance system was initiated in 1997 and surveillance data are considered complete beginning with calendar year 1998. In New York, acute pesticide poisoning has been a reportable condition since August 1990, and surveillance data are considered complete beginning with calendar year 1991. Although New Mexico has had a reporting requirement since 1993, its surveillance system was not fully developed until 2004, and surveillance data are considered complete beginning in 2005. Louisiana and Michigan have complete data beginning in 2001, and Iowa and North Carolina have complete data beginning in 2006. In each of the SENSOR-Pesticides states, complete data for a calendar year are generally available 5–12 months after the end of the calendar year.

(f) Periodicity of Reports

Printed reports are generally published annually.

TABLE 61.10 Acute Pesticide-Related Illness by Functional Class and Severity, SENSOR-Pesticides, 1998–2005

Pesticide functional class	Severity category				Total (%)
	Low	Moderate	High	Death	
Insecticides	3826	895	66	12	4799 (57)
Herbicides	935	156	6	0	1097 (13)
Fungicides	180	41	5	0	226 (3)
Fumigants	223	99	4	3	329 (4)
Disinfectants	499	80	7	1	587 (7)
Insecticides + fungicides	222	56	3	0	281(3)
Other[a]	507	74	11	4	596 (7)
Multiple[b]	417	114	5	1	537 (6)
Total	6809 (81%)	1515 (18%)	107 (1.3%)	21 (0.3%)	8452

[a]*This category includes rodenticides, plant growth regulators, insect growth regulators, wood treatment products, preservatives, and insect repellants.*
[b]*Pesticide product was classified into more than one functional class.*

(g) Findings

Between 1998 and 2005, a total 8452 cases of acute pesticide-related illness or injury were identified by the SENSOR-Pesticides program. A total of 4512 cases were work-related and 3940 were nonoccupational pesticide-related illnesses or injuries. These cases fell into the following classification categories: definite, 826 (10%); probable, 1793 (21%); possible, 5330 (63%); and suspicious, 503 (6%). The mean age was 36 years (range, 1 month–99 years). Males accounted for 53% of the cases (62% of occupational cases and 44% of nonoccupational cases).

Most illnesses were of low severity (80%) (Table 61.10). A total of 21 unintentional pesticide-related deaths were identified between 1998 and 2005. These included 3 agricultural workers, 4 nonagricultural workers, and 14 nonoccupational cases.

The average annual occupational pesticide poisoning incidence rate for 1998–2005 was 10.8 per million full-time equivalents (FTEs). FTE estimates, which are estimates of the number of full-time workers in the United States, were derived from the Current Population Survey conducted between 1998 and 2005 (Bureau of Labor Statistics, 2007). Figure 61.4 provides average annual incidence rates by state. The average incidence rates for all workers ranged from 2.2 per million FTEs in Arizona to 37 per million FTEs in Washington. The incidence rate per million workers also decreased from 13.1 in 1998 to 10.5 in 2005 (p value for trend by Poisson regression test <0.001).

A total of 1627 cases were employed in agriculture (39% of occupational cases where industry information was available) (Figure 61.5). The average annual agricultural

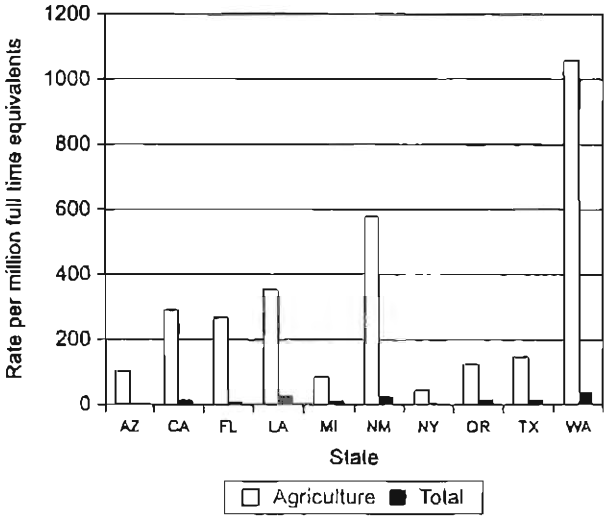
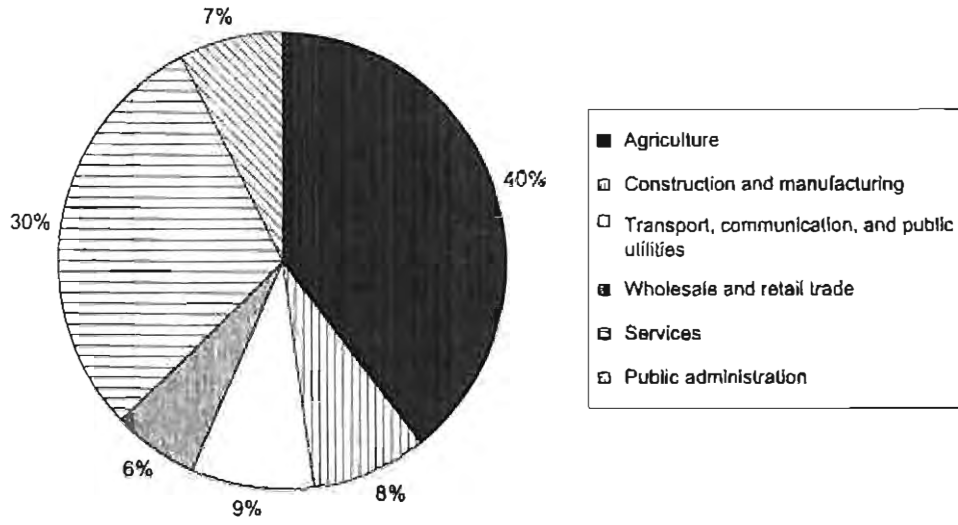


FIGURE 61.4 Average annual incidence rate of occupational pesticide poisoning by state, SENSOR-Pesticides, 1998–2005.

pesticide poisoning incidence rate for 1998–2005 was 239 per million FTEs. The incidence rate per million also decreased from 384 in 1998 to 318 in 2005 ($p < 0.001$). The annual agricultural pesticide poisoning incidence rate was as low as 174 per million FTEs in 2004. For the years 1998–2005, New York had the lowest average annual agricultural pesticide poisoning incidence rate (45 per million FTEs) and Washington had the highest (1057 per million FTEs) (see Figure 61.4).

A total of 2885 (34%) cases were employed in nonagricultural industries (61% of occupational cases where industry information was available). Most of these cases were employed in the services sector (see Figure 61.5).



Excludes cases with unknown industry (n = 358) and other industry (n = 23)

FIGURE 61.5 Distribution of occupational cases by industry, 1998–2005, SENSOR-Pesticides (n = 4131).

TABLE 61.11 Acute Pesticide-Related Illness by Functional Class and Occupational Status of Victim, SENSOR-Pesticides, 1998–2005

Pesticide functional class	Occupational status of victim			Total (%)
	Agricultural workers, n (%)[a]	Nonagricultural workers, n (%)[a]	Nonoccupational cases, n (%)	
Insecticides	635 (39)	1604 (56)	2558 (65)	4799 (57)
Herbicides	246 (15)	402 (14)	450 (11)	1097 (13)
Fungicides	125 (8)	53 (2)	48 (1)	226 (3)
Fumigants	146 (9)	139 (5)	44 (1)	329 (4)
Disinfectants	56 (3)	290 (10)	241 (6)	587 (7)
Insecticides + fungicides	175 (11)	57 (2)	49 (1)	281(3)
Other[b]	80 (5)	190 (7)	327 (8)	596 (7)
Multiple[c]	164 (10)	150 (5)	223 (6)	537 (6)
Total	1627 (19)	2885 (34)	3940 (47)	8452

[a]*Agricultural workers were defined as workers whose industry was coded as agricultural production, excluding livestock (1990 Census Industry Code (CIC) = 010); agricultural production, including livestock (1990 CIC = 011); and agricultural services (1990 CIC = 030; 2002 CIC = 0290) (U.S. Bureau of the Census, 1992). Nonagricultural workers included workers employed in all other industries.*

[b]*This category includes rodenticides, plant growth regulators, insect growth regulators, wood treatment products, preservatives, and insect repellants.*

[c]*Pesticide product was classified into more than one functional class.*

Information on the pesticides responsible for acute occupational pesticide-related illness is provided in Tables 61.10, 61.11, and 61.12. Overall, insecticides were responsible for 57% (n = 4799) of the illnesses. Among the insecticides, organophosphates (n = 1760), pyrethroids (n = 1305), pyrethrins (n = 335), carbamates (n = 276), mixtures involving cholinesterase inhibitors (n = 200), and mixtures of pyrethrins and pyrethroids (n = 162) were most commonly responsible.

Table 61.11 provides the distribution of pesticide functional classes by occupational status, including agricultural workers, nonagricultural workers, and nonoccupational cases. In all three categories, insecticides were responsible for the largest proportion of illnesses, followed by

TABLE 61.12 Top 15 Pesticide Active Ingredients Most Commonly Involved in Illness by Occupational Status, SENSOR-Pesticides, 1998–2005

Rank	Agricultural workers (N = 1627)[a]	No.	Nonagricultural workers (N = 2885)[a]	No.	Nonoccupational cases (N = 3940)	No.
1	Sulfur	186	Pyrethrins	326	Pyrethrins	525
2	Chlorpyrifos	121	Chlorpyrifos	170	Malathion	417
3	Glyphosate	90	Malathion	157	Permethrin	300
4	Cyfluthrin	81	Diazinon	131	Chlorpyrifos	259
5	Glyphosate	79	Resmethrin	130	Diazinon	196
6	Malathion	69	Permethrin	122	Cypermethrin	153
7	Methyl bromide	68	Glyphosate	113	DEET	142
8	Mancozeb	59	2,4-D	111	Tetramethrin	139
9	Carbofuran	58	Acephate	98	Glyphosate	120
10	Propargite	57	Silica gel	89	Propoxur	119
11	Imidacloprid	57	Cypermethrin	85	Phenothrin	111
12	Abamectin	56	Quaternary ammonium compounds	77	Cyfluthrin	90
13	Mepiquit chloride	52	Abamectin	71	*d-trans*-Allethrin	82
14	Paraquat dichloride	49	*d-trans*-Allethrin	64	Sodium hypochlorite	79
15	Carbaryl	47	Sodium hypochlorite	62	2,4-D	78

[a]*Agricultural workers were defined as workers whose industry was coded as agricultural production, excluding livestock [1990 Census Industry Code (CIC) = 010]; agricultural production, including livestock (1990 CIC = 011); and agricultural services (1990 CIC = 030; 2002 CIC = 0290) (U.S. Bureau of the Census, 1992). Nonagricultural workers included workers employed in all other industries.*

herbicides. Table 61.12 provides the active ingredients most commonly associated with illness, stratified by occupational status.

(h) Discussion

Among the strengths of these state systems is their reliance on a broad number of sources for case ascertainment. For example, the development of close ties with regional poison control centers has served to provide more complete reporting, particularly for illnesses from nonoccupational exposures. In addition, workers' compensation systems can be an important source of occupational cases as documented in California and Washington. Other states should consider improving access to workers' compensation data because these data are an important source of cases and can be used to periodically evaluate the completeness of the surveillance system.

Another strength of state-based surveillance systems is their access to personal identifiers. By knowing the identity of a case and the location of the exposure, prompt appropriate follow-up and intervention can be instituted. For example, in the case of an occupational pesticide-related illness, identification of the responsible workplace can result in an investigation to identify other workers with illness and to precisely target appropriate prevention programs. This is in contrast to national surveillance systems, which provide only anonymous data without personal identifiers.

Many state systems have found that maintaining physician (or any health care provider-based) reporting is resource intensive (Schnitzer and Shannon, 1999). When some states attempted to promote physician reporting through outreach activities, they found that case reporting increased but only as long as the outreach activities persisted. For physician reporting to be successful, the health care professional must be able to recognize pesticide-related illness and must comply with reporting requirements in a timely manner. Considering that pesticide-related illness is relatively rare and that health care professionals may not be trained in its recognition, the expectation that the preceding steps occur is likely overoptimistic. These issues are explored in more depth later.

Some states require laboratories to report when test results yield evidence for pesticide-related illness. The cholinesterase test is probably the most common laboratory test for recognizing pesticide-related illness; however, it is only useful for organophosphate and carbamate pesticides. An additional limitation of cholinesterase reports

is that only a minority of them are associated with known organophosphate or carbamate exposures. For example, in New York, where state law mandates that clinical laboratories report abnormally depressed cholinesterase levels, of 198 such laboratory reports received in 1995 and 1996, only 62 (31%) had known pesticide exposures (New York State Department of Health, 1997). The remaining cases were often tested as part of a presurgical evaluation and had either congenitally low levels or illnesses associated with low cholinesterase levels (e.g., liver disease, malnutrition, acute infections, and pernicious anemia; Vorhaus and Kark, 1953). Before deciding to adopt laboratory reporting for cholinesterase levels, consideration must be made for the resources needed to follow up on abnormal results.

The data provided by these state surveillance systems have proved useful. In addition to assessing magnitude and identifying risk factors, the SENSOR-Pesticides program has identified many emerging pesticide problems, usually in collaboration with DPR (Alarcon *et al.*, 2005; Calvert *et al.*, 2003, 2006, 2007a,b, 2008; Calvert and Higgins, 2009; CDC, 1999a,b,c, 2000, 2003, 2004, 2008a,b; Das *et al.*, 2001). These reports led to targeted efforts to prevent the recurrence of the identified pesticide problem. For example, after illnesses were found to be associated with the pesticides used in total release foggers (TRFs) (CDC, 2008a), New York began the process of classifying TRFs as restricted-use products (New York State Department of Environmental Conservation, 2008). SENSOR-Pesticides also recommended TRF package redesign, label modification, and public awareness campaigns. Another emerging pesticide problem that was detected involved illnesses associated with pesticide exposures at schools (Alarcon *et al.*, 2005). The publication of this report provided additional impetus for passage of legislation in several states that requires schools and school districts to reduce pesticide usage by implementing integrated pest management programs. Another report documented the problem with off-target drift of pesticides (CDC, 2003), specifically off-target drift into a low-income Hispanic community where many residents lacked health insurance. After this report was published, a law was passed in California that made growers liable for the uncompensated medical care provided to those who become sick from pesticides that drift from the grower's farm (State of California Food and Agriculture Code, Sections 12996.5, 12997.5, and 12997.7).

The SENSOR-Pesticides program has at least two limitations. First, the incidence rates are likely to be underestimates due to several factors (Azaroff *et al.*, 2002). Many individuals with pesticide-related illness are never ascertained because they neither seek medical care nor call appropriate authorities. Furthermore, because the signs and symptoms of acute pesticide-related illness are not pathognomonic, and because most health care professionals receive little instruction on this illness, many who seek medical care may not be correctly diagnosed. Even among those who are correctly diagnosed, many are not reported to state surveillance systems. Second, because only 12 states participate in the program, national estimates of pesticide poisoning are not available.

61.2.3 California Department of Pesticide Regulation

(a) Description

A 1971 California law requires physicians to report to the local health officer any disease or condition that they know or have reason to believe to be caused by pesticide exposure. The local health officer must notify the county agricultural commissioner (CAC) immediately. The health officer has 7 days to transmit the report to three state agencies, including the DPR. DPR maintains the California Pesticide Illness Surveillance Program (PISP), which supplements physician reports by reviewing reports of occupational cases forwarded to the California Bureau of Labor Statistics (CBLS) by workers' compensation insurers. In 2006, following developmental work funded by the U.S. EPA, DPR negotiated a contract with the California Poison Control System (CPCS). Under this contract, CPCS staff members offer to fulfill the reporting requirement on behalf of physicians who consult them.

CACs investigate all identified cases (including those involving nonagricultural exposures) of people exposed to pesticides in their jurisdictions. DPR provides instructions, training, and technical support for investigations. Instructions include directions for when and how to collect samples of foliage, clothing, or surface residues to document environmental exposures. As part of the technical support, DPR contracts with the California Department of Food and Agriculture's Center for Analytical Chemistry to analyze the samples. DPR also provides guidance to CACs in investigating sensitive situations such as drift into residential areas and suicides or attempted suicides. In cases of self-harm, DPR recommends that CACs seek primarily reports filed by first responders and exercise caution about making contact with victims or their families.

The CACs attempt to determine the circumstances of pesticide exposure. The investigators try to locate and interview everyone with knowledge of the event, including the affected people, the supervisors of people exposed at work, any other witnesses, and all applicators involved in the implicated application (if any) and their supervisors. Depending on what they find, investigators may track the source of the pesticide or ask the affected people to release relevant medical records. Investigators also inspect equipment and records to determine whether all laws and regulations were observed in acquiring and handling the pesticide(s) (Figure 61.6). If the investigation identifies noncompliance with laws or regulations, the CACs take action to enforce safe pesticide management.

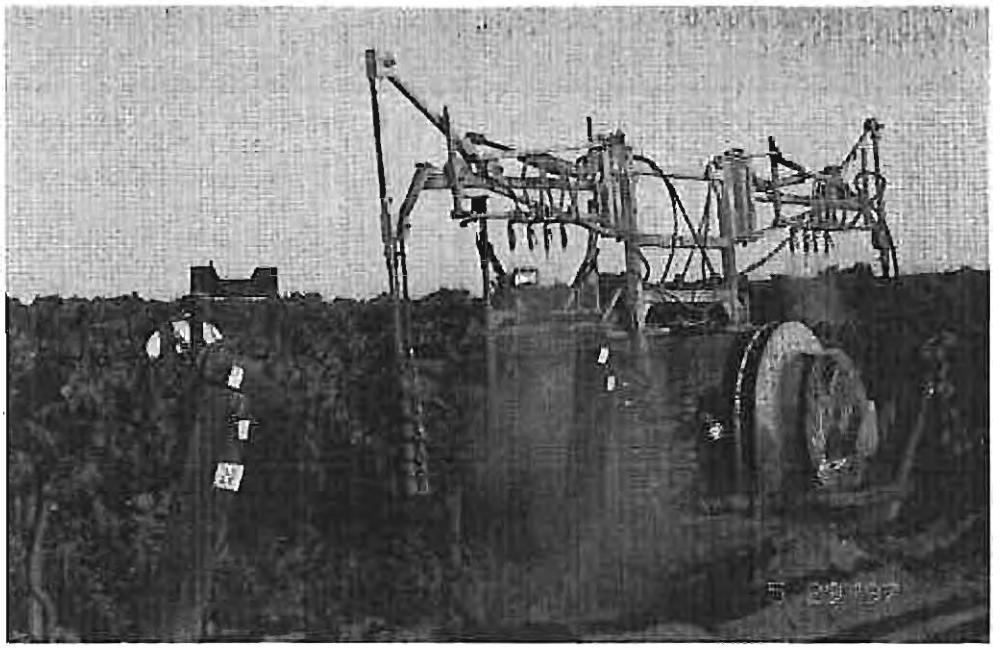


FIGURE 61.6 A twin-row, over-the-vine air blast sprayer applies pesticide to grape vines (courtesy of California EPA).

DPR scientists abstract data from the CACs' reports and any medical records received into a computerized database.[1] Software migration in 1998 provided the occasion to expand the database and organize its entries more logically. Cases from 1992 on have been upgraded to current standards.

(b) Case Definition

Physician reporting is required for "pesticide poisoning or any disease or condition caused by a pesticide." This requirement of California Health and Safety Code Section 105200 specifically states that such consultations may not be dismissed as "first aid"; doctors must report all suspected pesticide-related cases. The law also applies to cases of suicide or attempted suicide.

DPR recognizes that pesticide products are complex mixtures with various possible mechanisms of action. It is DPR policy to consider any adverse health effect that results from pesticide exposure to be a pesticide-related illness or injury. For purposes of overall classification, the primary toxic effects of the active ingredient(s) are not distinguished from effects of inert ingredients or impurities or from incidental reactions to product characteristics, such as nausea in response to odor.

DPR scientists use a 5-point ordinal scale to record a qualitative assessment of the likelihood that pesticide exposure caused or contributed to the reported illness or injury. When several signs or symptoms are reported, the scientist records the relationship of the complaint most likely to result from pesticide exposure. If the case record lacks critical information, scientists do not assign a relationship. For those cases that provide enough information to support evaluation, the relationship options consist of the following:

Definite: The signs and symptoms exhibited by the affected person are such as would be expected to result from the exposure described. Both medical evidence (e.g., blood cholinesterase levels or allergy testing) and physical evidence (e.g., residue on leaf samples or contaminated clothing) support the conclusion that the illness or injury was the result of the pesticide exposure.

Probable: There is close correspondence between the pattern of exposure and the illness or injury experienced. Medical and/or physical evidence may not be available. For example, although symptoms may be highly suggestive of cholinesterase inhibition, without results of cholinesterase testing, the case would have to be entered as probable rather than definite.

Possible: Health effects correspond generally to the reported exposure, but evidence is not available to support a relationship. The information available may be ambiguous. Headaches, nausea, and skin rashes, for example, all can be caused by many different things, and sometimes people are uncertain about the exact sequence of exposures relative to onset of ill health. Such uncertainty will cause a case to be entered as possible.

Unlikely: The exposure may be uncertain; the signs and symptoms reported are not typical of the suspected exposure, but the possibility that the victim is suffering the effects of pesticide exposure cannot be dismissed. Uncertain exposures may involve people far from the application site or who only handled tightly closed packages or thoroughly cleaned containers.

Unrelated: Evidence is available to demonstrate that the illness or injury was caused by factors other than exposure to pesticides. Sometimes, a product that initially was thought to be a pesticide turns out to be something else, such as a fertilizer or cleaner. Other times, the attending physician determines that the problem is infectious, not toxic.

Asymptomatic: The subject of the investigation was exposed to one or more pesticides but suffered no illness or injury. Cholinesterase depression without symptoms falls in this category. Such cases may, however, reflect lapses from good work practice.

Indirect: The illness or injury reported appears to have been caused not by pesticide exposure but by measures prescribed for avoiding pesticide exposure. People who develop heat stress through performing vigorous work in heavy protective clothing fall into this category, as do those who develop allergic reactions to rubber gloves.

Probable and definite cases generally are combined in data analyses. The category of possible relationship is the most ambiguous. In practice, it indicates that the people involved are known to have had contact with pesticides shortly before becoming ill or injured, but firm evidence is not available to indicate whether or not pesticide exposure caused their illness or injury. Because the "possible" category may contain more false positives than the definite/probable category, the PISP generally discusses possible cases separately from other categories. However, when determining the magnitude of acute pesticide-related illness and injury, cases classified as definite, probable, or possible are included in the sum, which is referred to as the number of pesticide-associated cases.

Unrelated, asymptomatic, and indirect relationships all indicate an assessment that pesticide exposure had nothing to do with health effects. Cases judged unlikely to relate to pesticide exposure are typically grouped with unrelated cases in reports.

(c) Data Source

Until CPCS began facilitating reports, CBLS provided 60–75% of all cases investigated. In 2007, physician reports transmitted through CPCS accounted for 36% of all cases and CBLS for 33%.

Since 1987, the DPR surveillance program has made an effort to collect cases related to antimicrobial/disinfectant products. Before 1987, there had never been more than 50 antimicrobial cases reported in a year. From 1988 through 1991, antimicrobial cases varied from approximately 800 to approximately 900 annually and then began a steady decline. In years without CPCS participation, CBLS supplied 80–98% of antimicrobial cases. In 2007, 34% of antimicrobial reports came from CPCS and 55% from CBLS.

(d) Target Population

This program attempts to capture any pesticide-related health problem evaluated by a California physician. Because of reliance on workers' compensation, occupational exposures are more fully reported than non-occupational exposures. CACs also investigate complaints registered by citizens and not by physicians. At their discretion, CACs forward to PISP the results of investigations into citizen complaints, and PISP scientists follow explicit standards to determine which to include in the illness surveillance database.

(e) Period of Time of Data Collection

Annual data are made available approximately 14 months after the end of each calendar year.

(f) Periodicity of Reports

Reports are released annually. The text of the report and tabulations summarizing the year's data are posted on the Internet at http://www.cdpr.ca.gov/docs/whs/YYYYpisp.htm (where "YYYY" represents a four-digit year). Reports from 1996 on remain accessible using this naming convention or via the DPR website at http://www.cdpr.ca.gov/docs/whs/pisp.htm. Hardcopy reports are available by request. An online interface at http://apps.cdpr.ca.gov/calpiq was announced with the release of the 2007 annual report. This interface allows any Internet user to query PISP data from 1992 through the most recent year released.

(g) Findings

PISP records and analyzes data in terms of both "cases" and "episodes." A case is the PISP's representation of a pesticide exposure and its apparent effects on one individual's health. An episode is an incident in which one or more people experience pesticide exposure from a particular source with subsequent development or exacerbation of symptoms.

From 1992 through 2007, PISP investigated 18,053 episodes involving suspected pesticide exposures to 26,324 individuals. After evaluating investigation reports, PISP scientists concluded that health effects on 18,125 people were at least possibly attributable to pesticide exposure encountered in 11,946 episodes. These totals include 8 pesticide-associated cases involved in 4 episodes identified in 1991; the 8 cases are excluded from further discussion in this chapter. The following findings apply to the 18,117 cases evaluated as definitely, probably, or possibly attributable to exposure in 11,942 episodes that occurred from 1992 through 2007. Table 61.13 presents demographic characteristics of the affected people and illustrates the preponderance of occupational exposures among case reports.

The total annual number of acute pesticide-associated illnesses ranged from 438 to 1856 during this period, with

TABLE 61.13 Demographic Distribution of Case Reports Received by the California Pesticide Illness Surveillance Program, 1992–2007, in which Health Effects Were Evaluated, After Investigation, as Definitely, Probably, or Possibly Related to Pesticide Exposure[a]

Age range	Occupational[b]				Nonoccupational				Total[c]
	Male	Female	Unknown sex	Total occupational	Male	Female	Unknown sex	Total nonoccupational	
0–4	0	0	0	0	147	125	1	273	273
5–14	7	3	0	10	282	290	11	583	593
15–17	100	68	0	168	52	60	1	113	281
18–24	1713	833	0	2546	133	119	0	252	2798
25–34	2648	1588	2	4238	178	191	0	369	4608
35–44	2021	1646	0	3667	229	241	3	473	4141
45–54	1114	989	1	2104	178	169	0	347	2452
55–64	490	313	0	803	98	118	0	216	1019
65+	74	43	0	117	92	105	0	197	315
Unknown	484	443	17	944	281	387	24	692	1637
Total	8651	5926	20	14,597	1670	1805	40	3515	18,117

[a]*A definite relationship indicates that both physical and medical evidence document exposure and consequent health effects. A probable relationship indicates that limited or circumstantial evidence supports a relationship to pesticide exposure. A possible relationship indicates that health effects correspond generally to the reported exposure, but evidence is not available to support a relationship.*

[b]*All exposures that occurred while the affected person was at work are considered occupational. Occupational exposures are more fully reported than nonoccupational exposures.*

[c]*Totals include five cases that could not be characterized as occupational or nonoccupational.*

an obvious downward trend over time. Table 61.14 shows the numbers of cases and episodes attributed annually to major pesticide classes. Antimicrobials and insecticides are implicated more often than other types of pesticides. Fumigants are implicated in the fewest episodes but have the largest average episode size. Except for the number of people affected by fumigant exposure, all of the columns in Table 61.14, including number of fumigant episodes, show proportionately similar rates of decline across time. The numbers of people affected by fumigants show increasing volatility, with several recent episodes affecting more than 100 people each.

California regulations identify people who work with pesticides as pesticide "handlers." This designation applies to anyone who mixes, loads, or applies pesticide and also to those who flag for aerial applications and to people who handle potentially contaminated equipment used for pesticide applications. The data summarized here include only eight flagger cases. Applicators are affected in more than half of all handler cases. Case reports on handlers have declined in proportion to the overall decrease in case reports. There is no clear trend in sources of handler exposure. Among agricultural handlers, approximately 40% did not know how they were exposed, and approximately 25% were directly exposed (e.g., by spills or splashes). Approximately half of nonagricultural handler exposures were direct (e.g., spills or splashes), and almost 25% involved airborne exposure, often to irritant gas produced by antimicrobial pesticides. In addition to the direct exposures mentioned previously, more than 10% of handler exposures (both agricultural and nonagricultural) occurred by direct spray from the application equipment.

Table 61.15 presents the impact of pesticide illness in case totals, lost work time, and hospitalization. It shows that herbicides and antimicrobials affect their handlers more often than they affect other people. Fumigants have the greatest tendency to affect nonhandlers, but handlers exposed to fumigants are more likely than others to experience disability or hospitalization. Figure 61.7 provides the distribution of cases by industry category. The agricultural industry accounted for the highest proportion of occupational cases (39%).

Table 61.16 lists the pesticides most frequently identified in investigations of illness episodes and the number of people exposed to each. The entry "unknown" identifies cases in which exposure to some pesticide was documented but investigators could not identify the implicated product. This is relatively common in nonagricultural exposures, in which people often have disposed of the pesticide by the time the case is investigated.

TABLE 61.14 Summary by Year and Pesticide Category of Reports Received by the California Pesticide Illness Surveillance Program, 1992–2007, in Which Health Effects were Evaluated, After Investigation, as Definitely, Probably, or Possibly Related to Pesticide Exposure[a]

	Pesticide category													
	Insecticides		Herbicides		Fungicides		Fumigants		Sanitizers		Other/unknown/ combinations		Total[b]	
Year[c]	Episodes[d]	Cases[e]	Episodes	Cases	Episodes	Cases	Episodes	Cases	Episodes	Cases	Episodes	Cases	Episodes	Cases
1992	356	610	94	96	121	169	40	84	602	708	129	183	1340	1850
1993	289	441	69	76	86	92	44	92	514	576	105	159	1104	1436
1994	271	520	64	68	67	106	31	33	467	533	60	69	959	1329
1995	303	570	75	89	77	110	40	105	506	563	96	156	1097	1593
1996	240	571	75	76	72	83	29	71	515	579	104	200	1034	1580
1997	247	445	85	102	75	128	37	84	393	432	83	158	920	1349
1998	161	265	57	59	65	70	22	23	371	468	67	112	742	997
1999	173	327	67	75	55	66	29	222	285	390	80	114	689	1194
2000	177	414	42	47	59	84	20	38	216	246	53	66	566	895
2001	170	212	38	39	30	34	28	46	235	245	34	43	535	619
2002	194	267	60	63	31	40	23	425	293	372	54	149	655	1316
2003	91	109	36	39	40	46	27	258	261	289	47	60	501	801
2004	94	301	40	66	30	35	19	36	287	311	42	85	512	834
2005	60	136	31	34	29	33	19	445	178	187	31	71	348	906
2006	58	91	16	16	24	57	13	74	119	149	32	50	262	437
2007	208	302	36	37	26	30	24	106	309	378	75	128	678	981
Total	3092	5581	885	982	887	1183	445	2142	5551	6426	1092	1803	11,942	18,117

[a] *A definite relationship indicates that both physical and medical evidence document exposure and consequent health effects. A probable relationship indicates that limited or circumstantial evidence supports a relationship to pesticide exposure. A possible relationship indicates that health effects correspond generally to the reported exposure, but evidence is not available to support a relationship.*

[b] *Ten episodes each included one or more people exposed to pesticides in addition to those encountered by all the people affected. These 10 episodes are counted both in the "other" column and in the column that represents the common exposure. They are counted as single episodes in the "total" column.*

[c] *All group episode cases are attributed to the year in which each episode was first identified.*

[d] *An episode is an event in which a single source appears to have exposed one or more people (cases) to pesticides.*

[e] *A case is the Pesticide Illness Surveillance Program representation of a person whose health problems may relate to pesticide exposure.*

TABLE 61.15 Impact of Health Effects Evaluated by the California Pesticide Illness Surveillance Program as Definitely, Probably, or Possibly Related to Pesticide Exposure, 1992–2007[a]

	Total cases	No. incapacitated[b]	Total days incapacitated[c]	No. hospitalized[d]	Days of hospitalization[e]
Agricultural[f]					
Insecticides					
Fieldworkers	1409	339	1360	13	27
Handlers[g]	450	147	593	10	30
Others	616	95	220	5	20
Herbicides					
Fieldworkers	100	33	76	2	9
Handlers	388	78	311	1	3
Others	58	5	12	0	0
Fungicides					
Fieldworkers	630	140	637	2	5
Handlers	229	45	192	3	20
Others	176	22	89	3	22
Fumigants					
Fieldworkers	202	13	42	2	2
Handlers	145	58	271	5	19
Others	1506	26	83	3	17
Antimicrobials					
Fieldworkers	27	5	26	0	0
Handlers	200	40	114	2	5
Others	276	51	147	2	7
Other/unknown/ combinations					
Fieldworkers	763	200	579	15	24
Handlers	210	51	269	1	2
Others	357	37	62	2	2
Total agricultural	7742	1385	5083	71	214
Nonagricultural					
Insecticides					
Handlers	573	116	305	19	85
Others	2533	600	2534	127	536
Herbicides					
Handlers	256	42	154	3	6
Others	180	30	82	7	16

(Continued)

TABLE 61.15 (Continued)

	Total cases	No. incapacitated[b]	Total days incapacitated[c]	No. hospitalized[d]	Days of hospitalization[e]
Fungicides					
Handlers	35	6	12	0	0
Others	113	30	68	1	16
Fumigants					
Handlers	53	16	119	1	1
Others	236	34	111	12	66
Antimicrobials					
Handlers	3761	664	2696	19	55
Others	2161	355	1570	43	143
Other/unknown/ combinations					
Handlers	81	12	31	3	8
Others	391	52	125	38	180
Total nonagricultural	10,373	1957	7807	273	1112
Overall total[h]	18,117	3342	12,890	344	1326

[a]*A definite relationship indicates that both physical and medical evidence document exposure and consequent health effects. A probable relationship indicates that limited or circumstantial evidence supports a relationship to pesticide exposure. A possible relationship indicates that health effects correspond generally to the reported exposure, but evidence is not available to support a relationship.*

[b]*Includes only cases of people who lost at least one full day of work. Excludes cases for which information on disability was not received.*

[c]*Counts full days lost from work. Disability of uncertain duration is counted as 1 day.*

[d]*Includes only cases with at least 24 h of hospitalization. Excludes cases for which information on hospitalization was not received.*

[e]*Counts 24-h periods of hospitalization. Hospitalization of uncertain duration is counted as 1 day.*

[f]*Agricultural cases are those in which the implicated pesticides were intended to contribute to the production of agricultural commodities (including livestock).*

[g]*Pesticide handlers are people who mix, load, or apply pesticides; flag for aerial applications; or handle equipment contaminated with pesticides. The totals reported here include only eight flaggers.*

[h]*Includes two cases that could not be characterized as agricultural or nonagricultural. Neither case involved hospitalization or disability.*

Of the 18,117 exposures reported, 5503 involved more than one pesticide. Included among the 5503 are 104 cases of exposure to two products with the same active ingredient. Consequently, cases are counted repeatedly in the Table 61.16 list of pesticides among those exposed to two or more active ingredients, any or all of which may have contributed to symptom development or exacerbation. In particular, most exposures to pyrethrins and pyrethroids also involve exposure to piperonyl butoxide or another synergist.

(h) Discussion

The California PISP maintains the oldest and largest database of verified information on adverse health effects of pesticides in the United States. It collects data on all types of pesticide products, including antimicrobials. The PISP database can be searched based on dozens of variables, including pesticide identity, type of formulation, toxicity category, type of health effect, circumstances of exposure, and age and sex of the people affected.

The program attempts to capture only those events that result in medical consultation, which provides both a threshold of severity and a preliminary screening by clinical judgment. In circumstances that suggest the existence of a hazard that would justify regulatory response, PISP scientists follow explicit standards that allow database entries to record exposures of individuals who did not seek medical attention.

Physician reporting is known to be incomplete because the program receives a high percentage of cases by alternative routes. Augmented by case finding via workers' compensation, the surveillance program has been instrumental in identifying opportunities for regulatory mitigation of occupational exposures. Poison control facilitation provides a much-needed source of information on domestic exposures. With the assistance of poison control, comparable insights into nonoccupational exposures are anticipated.

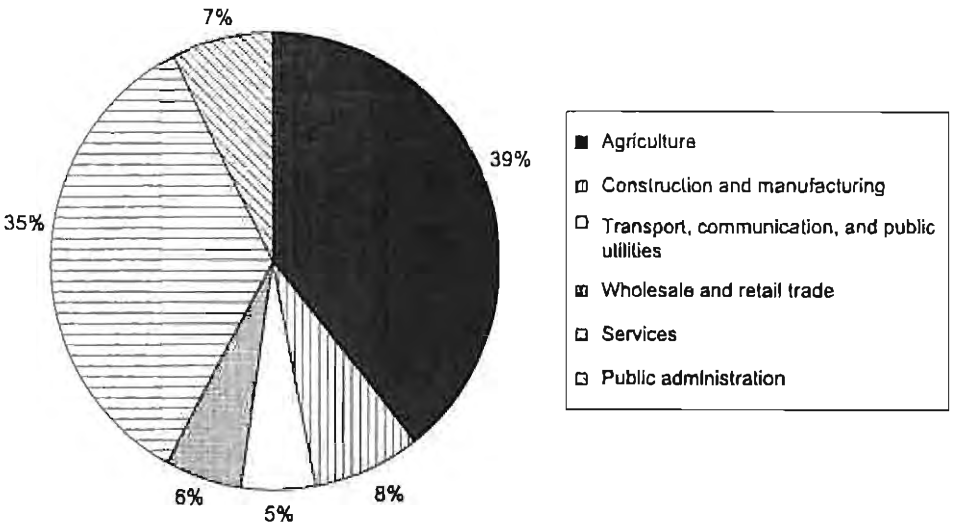


FIGURE 61.7 Distribution of occupational cases by industry, 1992–2007 (n = 14,354).

61.2.4 Bureau of Labor Statistics

(a) Description

Since the early 1970s, the Bureau of Labor Statistics (BLS) has published annual reports on the number of illnesses and injuries in private industry establishments. Beginning in 1992, the information provided in these reports was enhanced to provide additional information. Among the enhancements was the commencement of reporting of occupational pesticide-related illnesses and injuries. Note that data are available only when the pesticide-related illness or injury resulted in the worker being away from work for one or more days. Estimates of the number of workers with pesticide-related illness or injury that resulted in no lost time are not available.

The illness and injury estimates provided in these reports are obtained through an annual survey of employers (BLS, 1998). The survey collects data that employers are required to maintain under the Occupational Safety and Health Act of 1970. The disease estimates provided by the survey are based on a scientifically selected probability sample rather than a census of the entire population. The sample is selected to represent all private industry in the United States. Because the data must meet the needs of participating state agencies, an independent sample is selected for each state. Employers are stratified by their Standard Industrial Classification code and by employment size. Employers are then sampled from these strata. For the strata that contain the employers with the largest employment sizes, the allocation procedure places all of the establishments of the frame in the sample; as employment size decreases, increasingly smaller proportions of establishments are included in the sample. The response rate is generally more than 90% for sampled establishments. By a weighting procedure, sample units are made to represent all units within a sampling strata.

(b) Case Definition

Occupational pesticide-related illness and injury cases resulting in days away from work are recorded by employers as required under the Occupational Safety and Health Act of 1970.

(c) Data Source

An annual survey of employers (see Description).

(d) Target Population

This survey provides an estimate of the number of serious, nonfatal pesticide-related illnesses and injuries in private industry that involved days away from work. Excluded from the survey are self-employed individuals; farms with fewer than 11 employees (this accounts for approximately 50% of farms; National Agricultural Statistics Service, 2009); employers regulated by other federal safety and health laws (i.e., railroad transportation and coal, metal, and nonmetal mining); and federal, state, and local government agencies.

(e) Period of Time of Data Collection

Approximately 16 months are required to collect, compile, and publish findings following a given calendar year.

(f) Periodicity of Reports

Printed reports are published annually. Data are also available on the Internet at http://www.bls.gov/iif.

TABLE 61.16 Pesticide Active Ingredients Most Frequently Identified in Case Reports Evaluated by the California Pesticide Illness Surveillance Program as Definitely, Probably, or Possibly Related to Pesticide Exposure, 1992–2007[a]

Agricultural, excluding antimicrobials[b]		Nonagricultural, excluding antimicrobials		Antimicrobials	
Pesticide	**Case count**	**Pesticide**	**Case count**	**Pesticide**	**Case count**
Metam-sodium	842	Chlorpyrifos	392	Sodium hypochlorite	2671
Chloropicrin	571	Unknown	344	Quaternary ammonia	971
Sulfur	474	Diazinon	259	Chlorine	367
Chlorpyrifos	210	Malathion	250	Glutaraldehyde	336
Glyphosate	171	Glyphosate	171	Cyanuric acid	234
Propargite	169	Cyfluthrin	121	Unknown	225
Methamidophos	151	Cypermethrin	101	Calcium hypochlorite	135
Dimethoate	86	Sulfuryl fluoride	95	Phenolic disinfectants	132
Cyfluthrin	82	Propetamphos	78	Sodium chlorite	80
Methyl bromide	69	Permethrin	64	Pine oil	68
Paraquat	57	Copper naphthenate	59	Hydrogen chloride	57
Methomyl	53	Propoxur	57	Peroxyacetic acid	37
Unknown	51	Aluminum phosphide	43	Formaldehyde	29
Sulfur dioxide	49	Resmethrin	42	Trichloromelamine	25
Carbofuran	46	Boric acid	37	Ozone	18
Chlorothalonil	45	Methyl bromide	34	Kathon	16
Ddvp	45	Lambda-cyhalothrin	31	Chlorine dioxide	15
Aluminum phosphide	44	Bifenthrin	28	Halogenated hydantoins	14
Phosphine	37	Metam-sodium	26	Streptomycin	14
Diazinon	36	Acephate	25	Hydrogen peroxide	8
Mevinphos	36				
Sulfur	574	Piperonyl butoxide	702	Sodium hypochlorite	381
Chlorpyrifos	565	Pyrethrins	679	Quaternary ammonia	306
Methomyl	318	Synergist	449	Hydrogen chloride	227
Dimethoate	281	Chlorpyrifos	364	Hydrogen peroxide	109
Fenpropathrin	247	Permethrin	196	Peroxyacetic acid	106
Profenofos	244	Petroleum distillates	192	Phosphoric acid	102
Oxydemeton-methyl	223	Allethrin	171	Cyanuric acid	79
Petroleum oil	211	Diazinon	152	Ethyl alcohol	64
Chloropicrin	209	Rotenone	125	Pine oil	57
Myclobutanil	189	Methoprene	120	Phenolic disinfectants	57
Copper hydroxide	181	Cyfluthrin	105	Isopropyl alcohol	56
Imidacloprid	179	Propetamphos	79	Citric acid	55
Methyl bromide	162	Glyphosate	72	Edta	53
Esfenvalerate	156	Tetramethrin	69	Unknown	43

TABLE 61.16 (Continued)

Agricultural, excluding antimicrobials[b]		Nonagricultural, excluding antimicrobials		Antimicrobials	
Pesticide	Case count	Pesticide	Case count	Pesticide	Case count
Chlorothalonil	151	Acephate	59	Sodium carbonate	34
Abamectin	137	Fenoxycarb	57	Sodium metasilicate	27
Glyphosate	130	Cypermethrin	55	Trisodium phosphate	26
Propargite	126	Ddvp	55	Calcium hypochlorite	24
Permethrin	121	Petroleum oil	54	Formaldehyde	23
Diazinon	121	Propoxur	42	Sodium chlorite	18
				Iodine complex	18

[a]*A definite relationship indicates that both physical and medical evidence document exposure and consequent health effects. A probable relationship indicates that limited or circumstantial evidence supports a relationship to pesticide exposure. A possible relationship indicates that health effects correspond generally to the reported exposure, but evidence is not available to support a relationship.*

[b]*Agricultural cases are those in which the implicated pesticides were intended to contribute to the production of agricultural commodities (including livestock).*

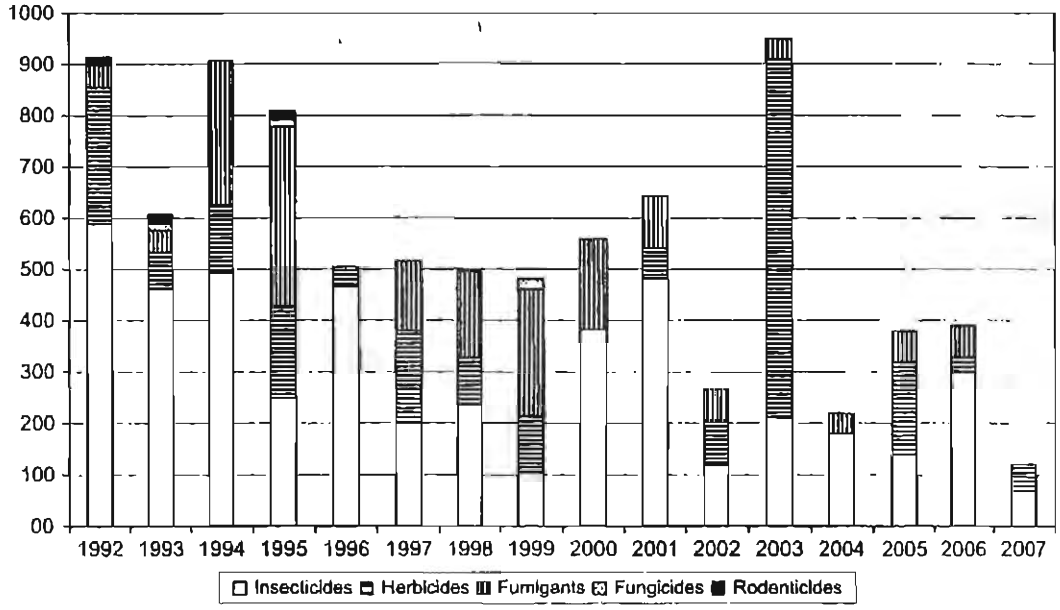


FIGURE 61.8 Number of occupational pesticide-related illness cases resulting in one or more days away from work by pesticide functional class, United States, 1992–2007 (data from Bureau of Labor Statistics, 2007).

(g) Findings

Between 1992 and 2007, the annual number of pesticide-related illness and injury cases ranged from 120 to 950 (Figure 61.8). In most of these years, insecticides were responsible for most cases. The exceptions were in 1995 and 1999, when fumigants accounted for the largest number of cases, and 2003 and 2005, when herbicides accounted for the largest number of cases.

(h) Discussion

BLS provides data on occupational pesticide-related illness only. In addition, pesticide-related illness data are available only for cases that result in lost work time, suggesting that only the more severe cases are recorded. Data on pesticide-related illness are available beginning in 1992. Because the number of identified cases is relatively small, and because this is a weighted sample and not a census of

TABLE 61.17 Counts of Unintentional Pesticide-Related Deaths by Pesticide Class Using Multiple Cause-of-Death Data, 1997–2005[a]

Pesticide-related cause of death (ICD-9 "E" code/ICD-10 code)	1997	1998	1999	2000	2001	2002	2003	2004	2005	Total
Insecticides of organochlorine compounds (E863.0/T60.1)	0	1	1	0	0	2	1	1	0	6
Insecticides of organophosphorus or carbamate compounds (E863.1, E863.2/T60.0)	2	5	6	1	2	2	5	3	4	30
Other and unspecified insecticides (E863.4/T60.2)	2	2	2	2	7	0	6	6	2	29
Herbicides or fungicides (E863.5, E863.6/T60.3)	6	2	3	3	3	2	4	4	6	33
Rodenticides (E863.7/T60.4)	4	0	4	2	1	5	2	0	2	20
Fumigants (E863.8)	4	0	—	—	—	—	—	—	—	4
Other and unspecified (E861.4, E863.3, E863.9, E980.7/T60.8, T60.9, X48, Y18)	16	14	12	3	6	5	3	2	4	65
Total	**34**	**24**	**28**	**11**	**19**	**16**	**21**	**16**	**18**	**187**

[a]*The underlying and all mentioned causes of death were coded using the International Classification of Diseases, 9th revision (ICD-9; World Health Organization, 1977) for years 1997 and 1998 and International Classification of Diseases, 10th revision (ICD-10; World Health Organization, 1992) for years 1999–2005. A separate code for fumigants is not available in ICD-10, and fumigant-related deaths after 1998 are likely placed in the "other and unspecified" category.*

the entire population, the estimates have the potential to vary widely from year to year. These limitations may explain the high number of cases in 1995 associated with fumigant exposure. Furthermore, because of the sparse number of identified cases, details on pesticide chemical class and active ingredients, industry and occupation, and circumstances surrounding the pesticide exposure are unavailable.

61.2.5 Vital Status Statistics: Multiple Causes of Death

(a) Description

The National Center for Health Statistics (NCHS) of the CDC releases a public-use vital statistics tape file for each data year. This file contains a data record for all deaths occurring annually in the United States. Each data record contains the underlying cause of death, other mentioned causes of death, and demographic data. The public-use data files can be purchased from the National Technical Information Service or the Government Printing Office, or they can be downloaded at the Mortality Statistics Branch, Division of Vital Statistics, NCHS website (http://www.cdc.gov/nchs/data_access/VitalStatsOnline.htm).

(b) Case Definition

Causes of death for the years 1979–1998 were coded using the *International Classification of Diseases*, 9th revision (ICD-9) [World Health Organization (WHO), 1977], and for years 1999–2005 the *International Classification of Diseases*, 10th revision (ICD-10) was used (WHO, 1992). Any of the following ICD-9 causes of death mentioned on the death certificate were included: 989.3, 989.4, E861.4, E863.0, E863.1, E863.2, E863.3, E863.4, E863.5, E863.6, E863.7, E863.8, and E863.9. Any of the following ICD-10 causes of death mentioned on the death certificate were also included: T60.1, T60.2, T60.3, T60.4, T60.8, T60.9, X48, and Y18. The pesticide class that corresponds to each of these codes is provided in Table 61.17. Separate codes are used for suicidal poisonings and poisonings possibly related to suicide. Suicides and possible suicides were excluded from the analyses provided here, and the corresponding codes are not provided. In addition, data on specific pesticide active ingredients are not available.

(c) Data Source

Multiple-cause-of-death public-use tape files have been released for each data year beginning in 1968. Data from 1997 to 2005 are provided here.

(d) Target Population

The 50 states, New York City, and the District of Columbia.

(e) Period of Time of Data Collection

Approximately 28 months are required to collect, compile, and make available data on the website following the end of a given calendar year.

(f) Periodicity of Reports

Public-use data tapes are available annually.

(g) Findings

Between 1997 and 2005, there were a total of 187 unintentional deaths related to pesticide exposures in the United States. During this 9-year period, the annual number of death certificates that mentioned pesticide-related illness and injury ranged from 11 to 34 (see Table 61.17). Insecticides were mentioned on 65 death certificates, making this the most common pesticide product type associated with pesticide-related deaths (see Table 61.17). The largest number of insecticide deaths involved organophosphate and carbamate compounds ($n = 30$).

The median age of death was 62 years. A total of seven (4%) deaths were among children younger than 10 years. Most of the pesticide fatalities were among those of white race (82%) and male (71%). However, blacks accounted for a slightly disproportionate share of cases (15%).

There are only limited data available on the circumstances of these pesticide-related deaths. A total of 66 (35%) occurred in the home, 2 (1%) occurred in a public building, 2 (1%) occurred in industry, 1 (1%) occurred on a farm, 3 (2%) occurred in a residential institution, 2 (1%) occurred on a street or highway, 1 occurred in a recreational setting, and 9 (5%) were noted to have occurred in an "other" location. Data on the location of the poisoning were not available for 101 (54%) of the deaths.

(h) Discussion

The multiple cause-of-death data are a useful source of data on pesticide-related deaths. However, only the most severe poisonings are included in this data source.

There has been little change in the number of pesticide-related deaths during the past 9 years. Furthermore, they are similar to the numbers reported for the years 1987–1996 (Calvert *et al.*, 2001). However, the numbers are lower than those reported in the 1970s and earlier (Hayes and Vaughn, 1977). Pesticide-related deaths numbered 97 in 1961 and 33 in 1974 (Hayes and Vaughn, 1977).

These data also demonstrate declines in the number of pesticide-related deaths among children younger than 10 years. Between 1997 and 2005, these children accounted for 4% of pesticide-related deaths. This is low when considering that children younger than 10 years comprise 13% of the U.S. population (U.S. Census Bureau, 2006). Furthermore, children younger than 10 years accounted for a lower proportion of all pesticide-related deaths during this 9-year period compared to the more distant past. Between 1987 and 1996, children younger than 10 years accounted for 10% of all pesticide-related deaths (Calvert *et al.*, 2001). In 1974, the proportion was 32%, and in many of the years before 1973 it was more than 50% (Hayes and Vaughn, 1977). Nonetheless, any childhood poisoning fatality is a tragedy and highlights the need for ongoing efforts to prevent pesticide access among children.

It appears that blacks no longer account for a highly disproportionate share of cases. In 2005, 13% of the U.S. population was black (U.S. Census Bureau, 2006), whereas between 1997 and 2005 blacks accounted for 15% of pesticide-related deaths. In contrast, between 1987 and 1996, blacks accounted for 26% of pesticide-related deaths.

The limitations of this data source are many. First, only the most severe (i.e., fatal) cases are included. Second, it is likely that not all pesticide-related deaths were included because some may have been coded to other nonspecific causes of death. For example, Hayes and Vaughn (1977) found that in 1973 and 1974, only 63% of accidental pesticide-related deaths were coded with the correct "E" code. Finally, details on the circumstances of exposure are not available on the multiple-cause-of-death data file. Collection of such details would require direct queries to the health care provider, as has been done in the past (Hayes, 1976; Hayes and Vaughn, 1977). However, information on each decedent in the multiple-cause-of-death data file includes age, race (including Hispanic origin), gender, state of residence (for pre-2005 data only), injury at work, marital status, and place of the accident.

61.2.6 National Hospital Discharge Studies: Colorado State University

(a) Description

Three previous studies were conducted by Colorado State University to estimate the nationwide incidence rates for hospitalized acute pesticide poisoning. These studies covered the intervals 1971–1973, 1974–1976, and 1977–1982. No similar national studies have been conducted using data after 1982.

We provide information on the most recent study (Keefe *et al.*, 1990). The nationwide poisoning estimates provided by this study are based on a stratified random sampling procedure involving all general care hospitals. States were placed in three strata based on the state's average rate of hospitalized pesticide poisonings for the years 1971–1976. Hospitals were sampled from each state; however, a higher proportion of hospitals were sampled from those states in the stratum with the highest hospitalized pesticide poisoning rates. Approximately 6% (368 hospitals) of all U.S. general care hospitals were included in the study.

(b) Case Definition

Hospitalized pesticide poisoning case.

(c) Data Source

A survey of general care hospitals (see Description). For the sampled hospitals, all medical records were reviewed. For patients with designated diagnoses from the *International Classification of Diseases*, 8th revision, *Adapted for Use in the United States* (ICDA), medical records were reviewed and appropriate data were abstracted.

(d) Target Population

This survey provides an estimate of the nationwide incidence of hospitalized pesticide poisoning cases in the United States.

(e) Period of Time of Data Collection

The last survey covered the time period 1977–1982.

(f) Periodicity of Reports

Printed reports are available for each of the later two studies (Keefe *et al.*, 1990; Savage *et al.*, 1980), and a review of the findings from the first two studies is also available (Keefe *et al.*, 1985).

(g) Findings

Between 1977 and 1982 in the United States, the annual number of hospitalized unintentional pesticide poisoning cases was estimated to average 2380 (range, 2127–2991). For this time period, the average annual number of hospitalized intentional pesticide poisoning cases was 454. The estimated annual number of occupational cases averaged 814 (range, 513–1077). The occupations with the greatest number of pesticide poisonings were farmers and commercial applicators. Organophosphates were most often involved in occupational pesticide poisoning cases, accounting for approximately 43% of occupational cases. Following are the top 10 pesticides, listed in order (highest to lowest), responsible for the most number of occupational pesticide poisonings that required hospitalization: parathion, malathion, methomyl, carbofuran, 2,4-D, mevinphos, methyl parathion, disulfoton, aldicarb, and glyphosate (Blondell, 1997). Children 0–4 years old accounted for 57% of all unintentional nonoccupational hospitalized pesticide poisoning cases.

(h) Discussion

These hospital discharge data were a useful source of data on severe pesticide poisoning cases but are no longer timely. Unfortunately, the most recently available data are from 1977–1982. Funding for this study was cut by the U.S. EPA in the early 1980s due to agency budget cuts and redirected priorities. Furthermore, because the data were obtained by a weighted sample and not by a census of all hospitals, some imprecision likely exists in the estimates.

61.2.7 National Hospital Discharge Survey: National Center for Health Statistics

(a) Description

The NCHS conducts an annual survey of nonfederal short-stay hospitals in the United States. The survey has been conducted annually since 1965. Data are collected from a sample of inpatient records acquired from a national sample of hospitals. The data represent a sample of discharges and not patients. Therefore, people with multiple discharges can be sampled more than once. Only general hospitals, children's general hospitals, or hospitals with an average length of stay of less than 30 days are included. Federal, military, and Department of Veterans Administration hospitals are excluded, as are hospital units of institutions (e.g., prison hospitals) and hospitals with fewer than six beds.

The National Hospital Discharge Survey uses a three-stage probability sampling design. Approximately 500 hospitals are sampled to acquire approximately 270,000 hospital discharge records. Collected samples are weighted to provide national estimates. Variables available in this data set include age, sex, race, marital status, month of admission, status at discharge, number of days of care, geographic region of the hospital, discharge diagnoses (up to 7) coded according to the ICD-9 categories, and source of payment. Occupation of the patient is not available (NHS, 2009).

(b) Case Definition

Hospitalized accidental pesticide poisoning case. Any of the following diagnoses are eligible for inclusion (ICD-9): E863.0, E863.1, E863.2, E863.3, E863.4, E863.5, E863.6, E863.7, E863.8, ad E863.9 (the pesticide class that corresponds to each of these codes is provided in Table 61.17). E863 is "accidental poisoning by agricultural and horticultural chemical and pharmaceutical preparations other than plant foods and fertilizers." Other codes are available to identify poisonings by cleaning products, petroleum products, corrosives, and unspecified solid and liquid substances, but these were not analyzed for this report. Suicides and possible suicides were excluded from the following analysis.

(c) Data Source

A survey of general-care hospitals (see Description).

(d) Target Population

This survey attempts to provide an estimate of the nationwide incidence of hospitalized pesticide poisoning cases in the United States.

(e) Period of Time of Data Collection

Annual surveys have been conducted since 1965. Data were analyzed for 2006, the most recent collected survey.

(f) Periodicity of Reports

Approximately 18 months are required to collect, compile, and publish findings for a given calendar year. Public-use data tapes are published annually. The E-code data are considered too unreliable to be included in the printed annual report.

(g) Findings

In 2006, there were two discharges with an E863 discharge diagnosis (accidental poisoning by agricultural and horticultural chemical and pharmaceutical preparations other than plant foods and fertilizers). One discharge involved a fungicide (E863.6), and the other involved an unspecified pesticide (E863.4) (NCHS, unpublished data). This sample is too small to provide a weighted estimate of the nationwide incidence of hospitalized pesticide poisoning cases.

(h) Discussion

The National Hospital Discharge Survey is not a reliable source of data for acute pesticide-related illness and injury. Less than half of the sampled hospitals provide data on E-codes (NCHS, unpublished data). For this reason, E-code data are not published in the annual reports of the National Hospital Discharge Survey.

The Nationwide Inpatient Sample (NIS) is another source of hospital discharge data and may contain more complete information on hospitalized pesticide poisoning cases. The 2006 NIS contains all discharge data from 1045 hospitals located in 38 states, approximating a 20% stratified sample of U.S. community hospitals. NIS data are available for purchase through the Healthcare Cost and Utilization Project website (HCUP, 2009).

61.2.8 South Carolina Hospital Discharge Surveys

(a) Description

The Medical University of South Carolina has periodically conducted a survey of hospitalized pesticide-related illness and injury in South Carolina. The initial survey was published in 1975 and included data from 1971–1973 (Caldwell and Watson, 1975). The latest report contains information on hospitalizations and emergency room visits for pesticide poisoning from 1997 to 2001. All 63 nonfederal hospitals in the state participated in the survey (Simpson *et al.*, 2004).

(b) Case Definition

Any inpatient medical record that contains one of the following ICD-9 codes: 989.2 (chlorinated pesticides), 989.3 (organophosphate and carbamate pesticides), and 989.4 (other pesticides).

(c) Data Source

A survey of all primary care hospitals in South Carolina that involved a detailed review of case charts by a board-certified physician.

(d) Target Population

This survey provides an estimate of the incidence of hospitalized pesticide poisoning cases in South Carolina.

(e) Period of Time of Data Collection

Periodic surveys have been conducted since the early 1970s.

(f) Periodicity of Reports

Reports and published papers provide the findings of the periodic surveys.

(g) Findings

The most recent survey found 148 hospitalized pesticide-related cases from 1997 to 2001 (mean = 29.6 cases/year) (Simpson *et al.*, 2004). Accidental, nonoccupational poisoning in adults and children accounted for 50% of the total number of hospitalized cases, 2% of cases were occupationally related, 40% were intentional ingestions, and 7% could not be classified. There were a total of 3 hospitalized and 9 emergency room visits for occupationally related pesticide poisoning, and 8 of these cases were from the agriculture industry. The ratio of outpatient to inpatient hospital care for pesticide poisonings was 5.8 to 1.0.

(h) Discussion

The mean number of hospitalized pesticide cases increased since the last published report (Caldwell *et al.*, 1997). The average annual number of hospitalized cases had declined from a peak of 79 cases/year in 1979–1982 to 22 cases/year in 1992–1996, but it increased to 29.6 cases per year in 1997–2001. The authors attributed the reduced numbers in 1992–1996 to the fact that the participation rate among hospitals was only 90% versus 100% participation in the most recent time interval.

An ongoing decline in occupationally related hospitalized cases continued to be observed (from a mean of 20 cases/year in 1979–1982 to 0.6 cases/year in 1997–2001). The authors attribute this decline to the success of pesticide applicator training programs, the licensing and certification of applicators using restricted pesticides, and the increasing use of pesticides with lower toxicity (i.e., pyrethrin/pyrethroid insecticides). Intentional nonoccupational exposures accounted for the highest proportion of pesticide-related hospitalizations (40%).

Only the most severe pesticide-related illnesses are captured by hospitalizations. The two most recent surveys also included information on outpatient emergency room visits.

which generally consist of lower severity cases. From 1997 to 2001, the overall ratio of emergency room visits to hospitalizations for pesticide poisonings was 5.8 to 1, although the rate for occupational pesticide poisonings was only 3:1. This finding could imply that occupational pesticide poisonings are of higher severity or that occupational cases are less likely to seek emergency room treatment.

61.2.9 National Agricultural Workers Survey

(a) Description

Since the early 1950s, the U.S. government has attempted to monitor the size, composition, and needs of the agricultural labor force. This function was transferred from the U.S. Department of Agriculture to the U.S. Department of Labor (DOL) in 1987, and the National Agricultural Workers Survey (NAWS) reached its present form in 1989.

NAWS cooperates with other government agencies by including questions that help measure the needs that can be addressed by migrant education, migrant health, and Census Bureau programs, among others. Since 1993, the U.S. EPA has contributed a limited set of questions designed to elicit information about health effects associated with pesticide exposure. In the October 1998 cycle, the health effects questions were expanded and improved. The number of health effects questions has varied since 1998 and is determined by the amount of survey funding received by DOL. The survey includes questions on medical history, use of medical services, participation in pesticide training, and housing conditions. Although the survey includes questions on general pesticide exposure (e.g., "In the last 12 months, did you load, mix, or apply pesticides?"), information on exposure to specific pesticide products or pesticide classes is not obtained. A complete occupational history for the year preceding interview is also obtained.

(b) Data Source

Respondents for this annual survey are selected by a multistage stratified process. The program defines 12 regions, each of which is further divided into several farm labor areas. Each farm labor area is an aggregate of counties that have similar agricultural and economic characteristics. At least three farm labor areas are selected from each region. One county is then selected from each selected farm labor area. Staff then compile lists of all farms within the selected counties and solicit cooperation from a random sample of the farms. At participating farms, the employees are sampled with a probability proportional to the square root of the size of the farm workforce. By sampling and recruiting workers at their worksite, this survey minimizes the undercounting of this population. After they are identified and recruited, the farm workers are interviewed face-to-face outside of working hours at home or another non-workplace location. The interview lasts approximately 1 h.

(c) Target Population

This survey provides national estimates on the U.S. crop labor force (note that workers involved in livestock production are excluded).

(d) Period of Time of Data Collection

The survey interviews approximately 500–1500 agricultural workers in each of three annual interview cycles. The number interviewed in each cycle depends on data needs and funding availability. Cycles begin in February, June, and October and last 15 or 16 weeks. These cycles were selected to reflect the seasonality of crop production and employment.

(e) Periodicity of Reports

Periodic reports presenting aggregate findings are available from the Office of the Assistant Secretary for Policy of the DOL. Public-use data files are also available at the NAWS website. Finally, if the desired data are not available in published reports or in the public-use files, specialized analyses can be requested from NAWS staff. Additional information on NAWS is available at its website (http://www.doleta.gov/agworker/naws.cfm).

(f) Findings

In 1999, with funding provided by NIOSH, NAWS included questions to determine if crop workers were poisoned by pesticides. This information was collected in two parts. First, NAWS asked crop workers if they were exposed to pesticides by "having them sprayed or blown on you," "spilled on you," or "when cleaning or repairing containers or equipment used for applying or storing pesticides." NAWS then asked if the crop workers became "sick or [had] any reaction because of this incident." Analyses of these data found that 3.2% of crop workers acknowledged exposure during the previous 12 months, of whom 43.4% reported getting sick or having a reaction (Calvert *et al.*, 2008). That is, 1.4% of U.S. crop workers attributed health effects such as skin problems (59%), eye problems (24%), nausea/vomiting (30%), headache (26%), and numbness/tingling (12%) to pesticide exposure during the preceding 12 months. In a separate NAWS question, 0.6% of all crop workers reported that in the past 12 months they had "received medical attention by a doctor or nurse due to pesticide exposure." To our knowledge, neither these nor similar questions to assess the incidence of pesticide poisoning were included in NAWS surveys before or after 1999. These estimates are much higher than other estimates. For example, an analysis of acute pesticide poisoning data from SENSOR-Pesticides and CDPR found an average annual acute occupational pesticide poisoning

incidence rate of 0.05% among all agricultural workers and 0.07% among farm workers.

(g) Discussion

NAWS can provide a useful source of data on acute pesticide poisoning among U.S. crop workers. Because it is a survey, it circumvents limitations found with surveillance systems that rely on physician reports. Physician reporting requires that the affected individual seeks medical care, that a diagnosis of pesticide-related illness or injury is made or suspected, and that the physician is aware of the need to report the suspected case. However, the NAWS findings on acute pesticide poisoning can be affected by whether the respondents correctly determined that they were poisoned and whether they were willing to report their status.

It would be helpful if future NAWS efforts repeated the pesticide poisoning questions from 1999. This would allow an examination of trends in acute pesticide-related illness among U.S. crop workers and would be helpful to assess the effectiveness of intervention efforts to prevent these illnesses.

FIGURE 61.9 A youth in Peru applying pesticides (courtesy of David L. Parker, MD, MPH).

61.2.10 Surveillance Efforts of International Organizations

Pesticide poisonings are a major concern throughout the world. The problem may be even greater in developing countries because of the impracticality of much personal protective equipment in humid tropical areas, because farmers are often illiterate, because the pesticide label is often not available in the local language, and because of employer disregard for worker health and safety (Figure 61.9) (Eddleston *et al.*, 2002). WHO estimates that there are up to 5 million acute unintentional pesticide-related illnesses and injuries per year, and that annually there are 20,000 deaths related to unintentional pesticide poisoning (Levine and Doull, 1992). Although it is well recognized that acute pesticide poisoning is a major public health problem in developing countries, surveillance of this condition in developing countries is scarce. The data available are not adequate to address the nature of the problem and are usually limited to *ad hoc* studies that are neither compatible nor comparable with each other, making estimates and evaluations difficult to undertake. To overcome this and assist developing countries in sound management of pesticides, efforts have been undertaken by some international organizations.

61.2.10.1 World Health Organization

In 1972, a WHO expert committee made the first global estimate of the number of cases of acute pesticide poisoning, on the basis of a theoretical model. Although these numbers raised some controversies, the information available showed that the problem existed, was important, and needed attention.

The International Program on Chemical Safety (IPCS) initiated a range of activities designed to characterize the true extent and severity of pesticide poisoning worldwide and set up the basis for surveillance systems. This included development of harmonized methods for governments to collect data on acute pesticide poisonings. A project titled "Epidemiology of Pesticide Poisoning – Harmonized Collection of Data on Human Pesticide Exposures" was launched. A common set of tools included a pesticide exposure record (Annex I) and pesticide poisoning severity score (PPSS) that was adapted from the poisoning severity score (PSS) developed by IPCS in collaboration with the European Commission and the European Association of Poison Centres and Clinical Toxicologists (Persson *et al.*, 1998).

Five countries (India, Indonesia, Myanmar, Nepal, and Philippines) participated in the project by collecting data using the developed tools and training medical staff on the diagnosis and treatment of pesticide poisonings. The project demonstrated the utility and acceptance of the tools for acute pesticide poisonings treated at hospitals, but it did not appear to reflect the situation concerning occupational and accidental exposures. It was recognized that population-based studies are required to collect information about cases that are not captured in hospital records.

As a continuation to the project, a surveillance protocol was developed to collect data on pesticide poisonings at the tertiary, secondary, and primary health care levels. The WHO/IPCS Pesticide Advisory Group that met in Washington in 2002 agreed on the protocol for the development of a national plan for the surveys. The acute poisoning protocol included, but was not limited to, an assessment of data availability, a sampling strategy for population-based surveys, an interviewing protocol for surveys, a standard case definition for acute pesticide poisoning, and standardization of poisoning severity based on a simplified version of the PPSS (WHO, 2002). Unfortunately, due to

financial constraints, it was not possible for WHO to test the methodology.

The Pan American Health Organization, through its Division of Health and Environment, implemented a project (PLAGSALUD in Spanish) that was financed by the Danish Agency for International Development on the occupational and environmental aspects of exposure to pesticides in the Central American subregion (including Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama) (Henao and Arbelaez, 2002). The 10-year project, which was initiated in 1994, aimed to significantly reduce the health problems related to pesticides and support the implementation of sustainable agriculture alternatives. Technical cooperation was provided in epidemiological surveillance, research, education, interinstitutional coordination, and the strengthening of legislation. One of the main results of this project was incorporation of surveillance of acute pesticide poisoning in the surveillance systems of the seven countries and also improvement of reporting in epidemiological surveillance.

The incidence rate of acute pesticide poisoning in the Central American subregion increased from 6.3 per 100,000 population in 1992 to 19.5 in 2000, but this was most likely due to an increase in surveillance efforts by the PLAGSALUD project. The mortality rates also showed a rising trend in the same period, with a risk of death of 0.3 per 100,000 population in 1992 increasing to 2.1 per 100,000 in 2000. These could be related to better surveillance and a greater awareness of pesticide poisoning by medical personnel. The study on underreporting conducted in the context of the PLAGSALUD project in 2001 showed that underregistration was still a problem, ranging from 80 to 99% in six countries where community surveys were conducted (Henao and Arbelaez, 2002).

61.2.10.2 Food and Agriculture Organization of the United Nations

Pesticide management is carried out within the overall framework of the Plant Production and Protection Division of the Food and Agriculture Organization (FAO). It is designed to work together with member countries and other international organizations as a partner to introduce sustainable and environmentally sound agricultural practices that reduce health and environmental risks associated with the use of pesticides. The *International Code of Conduct on the Distribution and Use of Pesticides* stipulates governments "to carry out health surveillance programs of those who are occupationally exposed to pesticides, and investigate, as well as document, poisoning cases"(Article 5.1.3) and "provide guidance and instructions to health workers, physicians, and hospital staff on the treatment of suspected pesticide poisonings"(Article 5.1.4) (FAO, 2002). The Regular Monitoring Report Form of the *Guidelines on Monitoring and Observance of Code of Conduct* asks governments to provide information on occupational exposure to pesticides and poisonings (FAO, 2006).

Within the context of the FAO Program for Community IPM in Asia, a field document was prepared in 2001 to pilot a farmer-based surveillance system in a community in Vietnam and Thailand. Each farmer was asked to fill out a form each time he or she sprayed. The information recorded included name, gender, address, date and spray event number, list of pesticides used, and home treatment used. Any sign or symptom experienced during or up to 24 h after spraying was circled on a body map that showed 29 potential signs and symptoms associated with pesticide poisoning (Murphy, 2002). For 12 months, 50 farmers in northern Vietnam recorded after every spraying session any adverse health effect and the pesticide that was used. Data were also gathered from 50 controls. Of the 1798 recorded spray operations, 8% were asymptomatic, 61% were associated with vague ill-defined effects, and 31% were accompanied by a least one clear symptom of poisoning. After 6 months of submitting self-reports and receiving feedback, the farmers in the intervention group had a significant reduction in self-reported spraying frequency and use of highly hazardous products (Ia/Ib) compared to the controls, as had their reports of adverse health effects of moderate severity (Murphy *et al.*, 2002).

61.2.10.3 Intergovernmental Forum on Chemical Safety

The Intergovernmental Forum on Chemical Safety (IFCS) was created in 1994 and provides an open, transparent, and inclusive forum for discussing issues of common interest and also new and emerging issues in the area of sound management of chemicals. IFCS plays a unique multifaceted role as a flexible, open, and transparent brainstorming and bridge-building forum for governments, intergovernmental organizations, and nongovernmental organizations including those from the private sector.

At the third forum of IFCS that was held in Bahia, Brazil, in 2000, one of the goals was "a report will have been prepared on the problem of acutely toxic pesticides and severely hazardous pesticide formulations and recommending sound management options." At IFCS Forum IV held in Thailand in November 2003, the governments made a series of recommendations on acutely toxic pesticides that included a recommendation to establish or enhance comprehensive national systems for surveillance and reporting of poisoning incidents affecting workers and communities (IFCS, 2003). Many developing countries lack the resources to establish and maintain the necessary surveillance programs and to obtain confirmatory laboratory testing for all possible cases of acute pesticide poisoning. Taking the WHO Pesticide Project Surveillance Working Group case definition (WHO, 2002) as a starting point, a paper was prepared by IFCS on a proposed

classification tool for acute pesticide poisoning (Thundiyil *et al.*, 2008). The aim was to provide a standard definition classification scheme for acute pesticide poisoning to enable its identification and diagnosis, especially at the field level, in rural clinics, and in primary health care systems. A standardized case definition and classification scheme for acute pesticide poisoning into categories of probable, possible, or unlikely/unknown is proposed. Based on the proposed criteria, laboratory confirmation is not absolutely necessary to meet the standard of a probable acute pesticide poisoning.

61.3 U.S. ENVIRONMENTAL PROTECTION AGENCY REGULATIONS

The U.S. EPA is responsible for implementing several regulations that promote the safe use of pesticides and that facilitate surveillance of pesticide-related injury and illness. These regulations are discussed in the context of collecting information about acute adverse effects of pesticides and the regulatory programs available to implement risk mitigation.

61.3.1 The Federal Insecticide, Fungicide, and Rodenticide Act

The U.S. EPA regulates the use of pesticides in the United States under the authority of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) (7USC§136). FIFRA was originally enacted in 1947 and underwent a major revision in 1972. No pesticide may legally be sold or used in the United States unless it bears a U.S. EPA registration number. It is a violation of the law for any person to use a pesticide in a manner inconsistent with its label. FIFRA gives the U.S. EPA the authority and responsibility for registering pesticides for specified uses, provided that such uses do not pose an unreasonable risk to human health or to the environment. In 1996, FIFRA was amended by the Food Quality Protection Act (FQPA), which included stricter pesticide safety standards, with the intent to better protect infants and children from pesticide hazards. FQPA required that there be a reasonable certainty that residues that result from use of a pesticide in or on any food pose no harm to human health.

FIFRA provides a number of remedies that can reduce and mitigate risks from pesticides. If subsequent information indicates that the use of a pesticide would pose unreasonable risks (pertaining to non-food-use pesticides) or a reasonable certainty or risk (pertaining to pesticide residues on food), the U.S. EPA has the authority to suspend or cancel its registration. If a pesticide warrants special handling because of its toxicity, it may be classified for restricted use. Pesticides with a restricted-use classification can be applied only by a certified applicator or under a certified applicator's direct supervision. States administer the certification programs, which require the certified applicator to demonstrate competency with respect to the use and handling of pesticides. The U.S. EPA also delegates to the states the responsibility and authority for enforcement of FIFRA (e.g., investigating and issuing penalties for a label violation).

Every U.S. EPA registered pesticide product has a pesticide label. The pesticide label provides directions on how to use a pesticide product and information on where it can be used, application rates (per treatment and per year), frequency of application, need for any required application equipment, and which pests can be controlled. The U.S. EPA classifies all pesticides into one of four acute toxicity categories based on established criteria (40 CFR Part 156). Toxicity is determined by acute animal tests for oral, dermal, inhalation lethality, and corrosive effects to the skin and eyes. Those pesticides with the greatest toxicity are placed in Toxicity Category I. Other pesticides are placed in the remaining three toxicity categories (Categories II–IV). A hazard signal word indicates the toxicity category of a pesticide product. The most hazardous pesticides (i.e., Toxicity Category I) are labeled "Danger," those with moderate toxicity (i.e., Toxicity Category II) are labeled "Warning," and less toxic pesticides (i.e., Toxicity Categories III and IV) are labeled "Caution." Precautionary statements on the label describe the protective clothing and other equipment that must be worn and used when handling or applying a specific pesticide product. They also specify the hazards to humans, children, domestic animals, and the environment. A statement of practical treatment may advise on the signs and symptoms of poisoning, provide information on first aid and antidotes, and provide a note to physicians on appropriate treatment. The label also specifies directions for safe storage and disposal.

The label may have a number of statements designed to reduce risk in addition to the requirements listed previously. The label must specify any restrictions on use for factors such as weather, time of day, season of the year, contamination of sensitive areas, and exposure of nontarget species. The label will indicate when an application requires use of enclosed tractor cabs, closed mixing/loading systems for liquids, ventilation, or mechanical flagging devices. Certain more hazardous application methods (e.g., air blast spraying) may be prohibited. Hygiene statements may require washing clothing after the application or prohibitions against wearing contaminated clothing the next day. After application, a restricted entry interval may be imposed whereby unprotected people are not permitted in the treated area for a time period specified on the label. Posting and/or notification of a treated area may be required to warn bystanders and others not directly involved in the application. Preharvest intervals may also

be required (i.e., the time period before harvest when use of the pesticide product is prohibited).

Formulation and packaging requirements can also be imposed under FIFRA to reduce pesticide risks. For example, the container size or percentage active ingredient may be limited. In addition, formulations may require ready-to-use solutions instead of concentrates, warning odors or dyes, or a bitter taste to discourage ingestion. Formulations may be limited to types (e.g., dry flowables) that limit exposure to handlers. Packaging design (e.g., water-soluble packets and lock-and-load container design) can also minimize handler exposure. Depending on acute toxicity, the pesticide may be required to be in child-resistant packaging.

61.3.2 Federal Reporting Requirements for Risk Information

Section 6(a)(2) of FIFRA requires pesticide registrants to submit to U.S. EPA information concerning adverse effects of their pesticide products. The purpose of the Section 6(a)(2) requirement is to help ensure that U.S. EPA pesticide registration decisions, as well as the terms and conditions of registration, were correct and that a pesticide can be used without posing unreasonable adverse effects to human health and the environment. Information submitted under this rule involves any and all toxicological and ecological studies, antimicrobial product efficacy failure data, and incident reports of injury or illness associated with use of the pesticide product. Incident reports may involve humans, domestic animals, wildlife, plants, surface or groundwater contamination, or property damage. Some registrants have elected to use the services of poison control centers to handle inquiries about adverse effects incidents concerning their products. When the U.S. EPA learns from a third party that a registrant knew about but did not report appropriate risk information, fines of several thousand dollars per case have been imposed on the guilty registrant.

For incident reporting of serious or rare incidents, the regulations specify that detailed information must be provided. For example, for more serious human incidents, documentation is requested on the pesticide agent, the circumstances of exposure, and evidence of the type and severity of adverse effects. Exposure circumstances include information on how the exposure occurred, the site where the pesticide was used, the situation, documentation of factors that may have contributed to exposure (e.g., early field reentry), and any other evidence that the label directions were not followed, if available. Adverse effects information includes the route of exposure, list of signs and symptoms, results from medical laboratory tests, type of medical care sought (i.e., none, clinic, hospital emergency department, private physician, poison control center, or hospitalization), time between exposure and onset of symptoms, and estimated duration or dose of exposure, if available.

Common or minor incidents, on the other hand, can be summarized as counts by product or active ingredient. There are some exceptions to the Section 6(a)(2) reporting requirement. Incidents are not required to be reported if facts establish that the exposure or the effect did not occur, if the registrant has been granted a written waiver from the U.S. EPA, or if the incident involved only minor skin/eye effects from residential use and a warning of such effects is provided on the pesticide label.

There are limitations related to the data submitted under the Section 6(a)(2) reporting requirement. Incident reports often consist of anecdotal reports or unproven allegations. Pesticide incidents must be reported even if the pesticide registrant does not think the adverse effect was caused by the pesticide product. Furthermore, pesticide registrants are not required to investigate incident reports. There are no criteria that must be met with respect to certainty of exposure, certainty of reported health effects, or certainty of the toxicological link between the exposure and health effects. However, Section 6(a)(2) data can be useful for identifying emerging pesticide problems, especially if several reports are received relating specific adverse effects to a specific pesticide product. Section 6(a)(2) is not available on the web but can be requested from the U.S. EPA.

61.3.3 National Pesticide Information Center

The National Pesticide Information Center (NPIC) provides information about pesticides and pesticide-related topics, including antimicrobial products, using a toll-free telephone service available to any caller in the United States, Puerto Rico, or the Virgin Islands. It also provides a wealth of pesticide-related information on its website. NPIC is funded by the U.S. EPA to provide objective, science-based information about a wide variety of pesticide-related subjects, including pesticide products, recognition and management of pesticide poisoning, toxicology, and environmental chemistry. The service can provide chemical, health, and environmental information on more than 1000 pesticide active ingredients incorporated into more than 16,000 different products registered for use in the United States. NPTN operates 7 days a week, excluding holidays, from 6:30 am to 4:30 pm Pacific time. NPTN can be reached by telephone at 1-800-858-7378 or at their website at http://npic.orst.edu.

61.3.4 Worker Protection Standard

Recognizing the need for increased worker protection from pesticide exposures, the U.S. EPA promulgated rules in 1974 known as the Worker Protection Standard for Agricultural Pesticides (WPS) (40 CFR 170). The aim of

WPS is to reduce pesticide exposures among agricultural workers. Workers employed at farms, forests, nurseries, and greenhouses are covered by WPS. By 1992, the U.S. EPA estimated that hired farm workers alone experienced up to 10,000–20,000 illnesses and injuries from pesticide exposures each year (U.S. EPA, 1992) and concluded that the WPS was inadequate in its requirements and scope of coverage. That year, the U.S. EPA revised and expanded the WPS rules to include changes in labeling, coverage of more workers and agricultural operations, prohibition of employer retaliation against workers attempting to comply with the standard, and the following requirements: notification of workers about pesticide applications; restriction of reentry into pesticide-treated areas; and provision of PPE, decontamination supplies, emergency assistance, and pesticide safety training.

61.4 EVALUATING SURVEILLANCE SYSTEMS

The purpose for evaluating surveillance systems is to ensure that available surveillance resources and funding are directed at important public health problems and to determine whether the surveillance systems are operating efficiently and effectively. Guidelines for evaluating surveillance systems are available (CDC, 2001c) and are briefly summarized here. Public health surveillance systems should be evaluated periodically, and the evaluation should include recommendations for improving the systems' quality, efficiency, and usefulness.

When evaluating surveillance systems, it is important to describe the public health importance of the health event of interest. The information provided previously in this chapter supports the public health importance of acute pesticide-related illness and injury. Surveillance data indicate that a large number of cases occur annually, some of which are fatal. In addition, epidemiologic data suggest that acute poisoning is associated with long-term health effects (Rosenstock *et al.*, 1990; Savage *et al.*, 1988; Steenland *et al.*, 1994). Pesticides are toxic substances and are used in large quantities in both the indoor and the outdoor environment (Kiely *et al.*, 2004). Because society allows pesticides to be disseminated into the environment, society also incurs the obligation to conduct surveillance on the health effects of pesticides. Finally, acute pesticide-related illness and injury are preventable through regulation and enforcement, appropriate training, and by carefully following the instructions on the pesticide label. Data from public health surveillance systems can be used to guide the planning, implementation, and evaluation of these measures.

It is also important to assess the usefulness of surveillance systems. This can include describing the actions taken as a result of using data from the surveillance system (e.g., policy changes, regulatory changes, and clinical practice changes) and describing other anticipated uses of the data (e.g., detecting disease magnitude and trends, detecting new pesticide hazards or new populations at risk, detecting epidemics, stimulating epidemiological research, and assessing the effectiveness of interventions).

The attributes of the surveillance system should also be evaluated. Because some attributes can conflict with other attributes (i.e., excelling in one attribute may hamper the ability to satisfy another attribute), it is important to identify and strengthen those attributes that are most important to a particular surveillance system. It should be recognized that it may not be possible to fully achieve the less important attributes. The attributes that should be evaluated are as follows:

Sensitivity: What proportion of the total number of cases or total number of outbreaks is identified by the system? Sensitivity is influenced by whether cases seek medical care, whether those who seek care are correctly diagnosed, and the likelihood that the correctly diagnosed case will be reported to public health authorities. Surveillance conducted through surveys of individuals at risk of pesticide poisoning (e.g., farm workers) can be affected by whether subjects can correctly determine that they were poisoned and whether they are willing to report their status. Substantial resources may be required to evaluate this attribute (e.g., extracurricular efforts to determine the annual incidence of the condition in the community). Systems without high sensitivity can be useful for monitoring trends, as long as the sensitivity remains relatively constant.

Flexibility: How adaptable is the system to changing needs or operating conditions? A flexible system can handle changes in case definitions, reporting sources, data elements, and outcomes/diseases/exposures. Flexibility is a characteristic met by many pesticide poisoning surveillance systems.

Simplicity: This refers to the structure of the system and its ease of operation. The surveillance system should be as simple as possible. There are several measures to be considered. Is the case definition easy to apply? Are there multiple reporting sources? How much time is spent collecting data? What is the mechanism for transmitting case information/data? How extensive are the staff training requirements? What type of data analysis is required? Who are the users of the data and what is the mechanism for distributing reports/data? Due to the complexity and large number of pesticides, pesticide poisoning surveillance systems are rarely simple.

Data quality: This reflects the completeness and validity of the data being collected by the pesticide poisoning surveillance system. It can be assessed by examining the proportion of cases with "unknown" information for various variables or data elements that the surveillance system attempts to capture. It is influenced by

two other attributes: the sensitivity and positive predictive value. It is also influenced by the level of training of surveillance system staff and the care taken in data management. Data quality impacts two other attributes: acceptability and representativeness. High data quality will improve the acceptability of the surveillance system and should also improve its representativeness.

Acceptability: This attribute assesses the willingness of individuals and organizations to participate in the system. It can be assessed by examining the participation of various potential reporting sources, interview completion rates, extent of missing data, and timeliness of reporting. Several factors influence acceptability. What is the public health importance of the health event of interest? Is there timely recognition of a stakeholder's contribution? Are the time and personnel costs onerous? Have reporting laws been enacted? Does the system provide high-quality, useful information?

Positive predictive value: It is important to maximize the proportion of cases reported to the system that actually have the condition. This is because system resources are used to confirm and investigate cases reported to the system. A system with a low predictive value for reported cases suggests that resources may be wasted when those cases are investigated. Inappropriate outbreak investigations may be conducted if a high number of false positives are reported. The predictive value is related to the sensitivity and specificity of the case definition and the prevalence of the condition in the population. Increased specificity and prevalence leads to an increased positive predictive value.

Representativeness: This assesses whether findings from the surveillance system can be generalized to the entire target population. It is also important to attempt to identify any population subgroups that may be systematically excluded from the surveillance system. Because surveillance data are often used to calculate morbidity and mortality rates, thought should be given to ensure that the denominator, which is often obtained from a different source (e.g., the Current Population Survey, which consists of data collected by the U.S. Census and the Bureau of Labor Statistics), is comparable with respect to the demographics of the surveillance data in the numerator. As with sensitivity, substantial resources may be required to assess this attribute. Special studies may be useful that seek to identify all cases and then compare them to those cases reported to the system.

Timeliness: This refers to the time interval between each step in the surveillance system. Among the more important time intervals to assess are the length of time between an event and its being reported to the surveillance system, the time required to identify trends and outbreaks, and the time required to institute interventions. The importance of timeliness depends on the urgency of the public health problem and the availability of effective control measures. The pervasive use of computer technology and the Internet, and growing use of electronic health information and electronic medical records, holds promise for improving this attribute.

Stability: This attribute refers to the availability and reliability of the public health surveillance system. Measures can include assessing how often the surveillance system is fully operational and the difference between the desired amount of time and actual amount of time required to collect, receive, manage (including data entry and edit checks), and disseminate data. A lack of sufficient resources can affect stability. Unreliable and unavailable surveillance systems can hamper public health interventions.

(a) Discussion

When evaluating a surveillance system, conclusions and recommendations should be provided. An assessment should be made as to whether the surveillance system should be continued (i.e., Is the health condition under surveillance important? Can justification be made for the resources used by the system?). If it is to be continued, the need for any modifications to the system should be identified.

Finally, when making recommendations for modifications, it is prudent to recall that the costs and attributes of the system are interdependent. Improvements in many of the attributes (sensitivity, representativeness, timeliness, data quality, and stability) will likely increase the costs of the surveillance system. In addition, improvements in one attribute may affect performance of another attribute. For example, improvement in positive predictive value may compromise sensitivity and may reduce simplicity. Therefore, these consequences should be considered when recommending modifications.

61.5 CASE DEFINITION FOR ACUTE PESTICIDE-RELATED ILLNESS AND INJURY

A public health surveillance system depends on a clear case definition for the condition under surveillance. It is used to identify individuals with a health outcome of interest. The standardized case definition improves specificity and allows for comparability across geographic areas, time periods, and various reporting sources. It is needed both in epidemiologic studies and to conduct surveillance. The case definition for acute pesticide-related illness and injury can be simple or complex. Those that are used in the surveillance systems described previously are not identical but vary across the systems. In some instances, the clinical diagnosis may be the basis of the case definition. For example, conducting surveillance of unintentional

pesticide-related fatalities using vital status statistics involves identifying death certificates that contain ICD-9 E codes or ICD-10 codes specific for accidental pesticide poisoning. These ICD-9 and ICD-10 codes are supplied by the health care professional who completed the death certificate. Similarly, data from BLS and AAPCC often involve medical outcome data supplied by the health care provider.

Some case definitions may make a determination that differs from the clinical diagnosis. This may occur when the case definition provides guidelines for assessing the certainty of the evidence regarding exposure and health effects. An example of this is the case definition for acute pesticide-related illness and injury developed for the National Public Health Surveillance System (NPHSS). In contrast, the purpose of the clinical diagnosis is to guide the immediate treatment course for an ill individual. In addition to employing much of the same information used by a surveillance system, a clinical diagnosis often also involves a subjective understanding of a patient's sensitivity to exposure. This subjective understanding may not be available for consideration by the surveillance system.

61.5.1 The National Public Health Surveillance System Case Definition

The NPHSS is a conceptual framework for public health surveillance based on a consensus of practicing epidemiologists at the local, state, and national levels (Meriwether, 1996). Goals of the NPHSS include prioritizing surveillance activities and securing the necessary resources to conduct these activities. Acute pesticide-related illness and injury is one of the conditions identified for inclusion in the NPHSS.

The acute pesticide-related illness and injury case definition for the NPHSS was developed using a modified nominal group process (Jones and Hunter, 1995). The group consisted of experts from federal agencies [NIOSH, U.S. EPA, and National Center for Environmental Health (NCEH)], nonfederal agencies (Council of State and Territorial Epidemiologists and Association of Occupational and Environmental Clinics), and state health departments or other state designees. Prior to the first meeting of the group, a proposed case definition was distributed. During the first meeting in September 1995, the case definition was reviewed and revisions were made. Following the meeting, a revised case definition was provided to each of the participants, along with a classification exercise that consisted of three "test" cases that each participant classified using the case definition. The classification exercise identified the need for several modifications to the case definition. Additional meetings held in April 1996 and November 1997, two subsequent classification exercises, and additional iterations via e-mail continued this process until consensus was achieved.

Because public health agencies seek to prevent all adverse effects from regulated pesticides, the case definition is intended to be applied to any acute adverse health effect resulting from exposure to a pesticide product, including health effects due to an unpleasant odor, injuries from explosion of the product, allergic reactions, and effects associated with inert ingredients. The case definition requires the collection of information in three areas: pesticide exposure, health effects, and evidence supporting a causal relationship between exposure and effect. A case of pesticide-related illness or injury is classified as being definite, probable, or possible. The specific classification category is chosen depending on the level of certainty of exposure, whether health effects were observed by a health care professional, and whether there is sufficient toxicologic information to support a causal relationship between the exposure and health effects. The cases classified into these categories meet the following criteria:

- Documentation of two or more new adverse health effects that are temporally related to a documented pesticide exposure
- Consistent evidence of a causal relationship between the pesticide and the health effects based on the known toxicology of the pesticide from commonly available toxicology texts, government publications, information supplied by the manufacturer, or two or more case series or positive epidemiologic investigations.

When insufficient toxicologic information is available to determine whether a casual relationship exists between the pesticide exposure and the health effects, a case is classified as "suspicious." This category is assigned when minimal information is available on the human health effects that can be produced by the pesticide in question (e.g., when there are less than two published case series or positive epidemiologic studies linking health effects to the putative exposure agent).

When convincing evidence for an exposure–health effect relationship is not present, the case is classified as "unlikely." A classification of "not a case" is assigned when there is strong evidence that no pesticide exposure occurred, when no new postexposure signs or symptoms were reported, or when there is definite evidence of a nonpesticide causal agent.

The case definition is complex. It requires knowing how to obtain information on each of the following three criteria: exposure (i.e., knowing what environmental and medical tests should be conducted and what questions to ask), health effects (i.e., the ability to review medical records and to solicit a medical history), and the causal relationship (i.e., knowledge about how to find and use appropriate toxicological and medical references). It also requires knowledge and experience with assessing whether the exposure was sufficient to produce the observed health effects. Because of the skills, knowledge, and experience that are required to use this case definition, it is likely that for any

given case, the extent of agreement among raters on a classification category for a given case will not be total.

There are several reasons for the complexity of the case definition. One is that there is no "gold standard" for identifying pesticide-related illness and injury (i.e., there is no symptom, sign, or test that is definitive or pathognomonic for this condition). Therefore, identifying cases of pesticide-related illness and injury requires assessment of available information on exposure, health effects, and causal relationship. Unfortunately, because there is no gold standard, it is difficult to determine the case definition's sensitivity, specificity, and positive predictive value. Likewise, it is difficult to assess the degree of misclassification that arises by using the case definition. However, we think most would argue that this case definition reduces misclassification compared to other less rigorous definitions. Another reason for the complexity of the case definition is that it covers all pesticide chemical classes and active ingredients (i.e., literally hundreds of different chemicals). This allows the case definition to be flexible.

This case definition is also resource intensive. It requires having trained staff to collect and assess the information needed for case classification. It also requires staff to code and key the data into a database so that the data on each criteria can be organized and analyzed.

A major strength of the standardized case definition and the standardized variables (described previously) is that they allow data from participating surveillance systems to be compared and aggregated. This aggregation has permitted the enhancement of knowledge about acute pesticide-related illness and injury. With this knowledge, the goal of surveillance can be and has been realized: targeting public health resources toward the prevention of acute pesticide-related illness and injury.

In conclusion, a case definition is needed to identify individuals with pesticide-related illness and injury. Currently, the case definition varies across surveillance systems. Where adequate resources exist, it is recommended that the case definition for the NPHSS be used. Regardless of the case definition that is used, all serve the purpose of identifying cases so that appropriate interventions can be targeted.

61.6 LIMITATIONS OF PESTICIDE POISONING SURVEILLANCE DATA

When examining surveillance data, one needs to be mindful of its limitations. A discussion of these limitations follows.

61.6.1 Denominators

A denominator is needed to calculate rates. Comparing the rate of the condition across different groups is needed to identify high-risk populations and to evaluate risk factors. Counts alone of a condition's occurrence may have little value for identifying disease risk factors. The difficulty of finding appropriate denominator information is one of the most obvious limitations of surveillance data.

National populations provide one type of denominator for surveillance data. The absolute counts reveal striking differences in pesticide mortality between industrialized and developing nations. Adjusting for relative population size, through the use of rates, emphasizes the disparity (Table 61.18).

More refined rate estimates require a denominator that consists of the number of pesticide-exposed individuals. Unfortunately, such estimates are generally either imprecise or unavailable. For occupational exposures, the most straightforward denominator is the number of pesticide-exposed individuals in the occupational group of interest (e.g., the number of licensed pesticide applicators). Regrettably, this information is unavailable. Little information is available on the magnitude of most pesticide-exposed workers, such as unlicensed applicators, or individuals who perform agricultural work. The transient nature of the agricultural workforce in many areas, and the fact that some agricultural workers may have undocumented U.S. immigrant status (i.e., lack of a U.S. visa or other immigration document), further complicates developing reliable denominators for pesticide-exposed agricultural workers. Considering variations in exposure among the agricultural workforce adds complexity to the problem (e.g., what pesticides are used, method of application, duration of use, and use of personal protective equipment).

To calculate rates for nonoccupational pesticide-related illness, denominator information is needed on the use of pesticides by homeowners. This information is even more difficult to acquire than estimates of occupational pesticide users. Possible surrogates include data from a U.S. EPA 1990 survey of home and garden pesticide use that provided estimates of the number of containers and number of applications of pesticides for all households in the United States (Whitmore *et al.*, 1992).

Denominators can also be derived from pesticide use databases. Nationally, some survey data are available on the annual quantities of agricultural pesticides that were used (U.S. Department of Agriculture, 1998). Approximately every 2 years, the U.S. EPA publishes a report on pesticide sales and usage. The most recent report was published in 2004 and provides pesticide usage data through 2001 (Kiely *et al.*, 2004). This document provides information on pesticide expenditures (in U.S. dollars) and amounts of pesticide active ingredients used (in pounds) both worldwide and in the United States. The data provided in that report are collected by various sources, including the U.S. EPA, the U.S. Department of Agriculture, and various private vendors.

In addition, at least six states mandate some form of pesticide use reporting: Arizona, California, New Hampshire,

TABLE 61.18 Annual Fatalities Ascribed to Pesticide Intoxication by Country

Country (source of data)	Time period	Average annual no. of deaths (SD)	% Self-inflicted	Approximate population of country (millions)	Average annual rate of all pesticide fatalities/million	Average annual rate of unintentional pesticide fatalities/million[a]
Costa Rica (Wesseling *et al.*, 1993)[b]	1980–1986	40.4	84	2	20.2	3.2
Jordan (Abdullat *et al.*, 2006)	1999–2002	35	64	5.2	6.8	2.4
South Korea (Lee *et al.*, 2009)	1996–2005	2536	85	48	53.2	7.9
Sri Lanka (de Alwis and Salgado, 1988)[c]	1975–1983	1032 (200)	66	14.5	71.2	24.2
Sweden (Persson *et al.*, 1997)	1969–1994	0.84	85	8	0.1	0.02
United Kingdom (Thompson *et al.*, 1995)	1990–1991	22	66	50	0.4	0.01
United States (see Section 61.2.5)[d]	1997–2005	21	—	285	—	0.07

[a]*Excludes self-inflicted poisoning deaths.*

[b]*Data presented are crude figures derived from official sources and are believed more likely to be comparable to the data in the other entries in this table. A chart review conducted by Wesseling et al. (1993) identified additional cases (revised annual number of deaths per year = 61.3) and called into question the percentage of deaths that were self-inflicted (revised estimate = 62%).*

[c]*Percentage self-inflicted based on review of a sample.*

[d]*These data contain only unintentional cases.*

New York, New Jersey, and Oregon. The most comprehensive pesticide use reporting systems are found in California and New York. Beginning in 1996 in New York, commercial applicators must maintain records on all pesticide applications. The record for each application must include the U.S. EPA registration number, the name of the pesticide product, the amount applied, and the date and location of the application. Individuals who sell pesticides must maintain records on each pesticide purchase, including the U.S. EPA registration number, the name of the pesticide product, the date and amount purchased, and the intended location of the pesticide application. Information on all applications and pesticide purchases must be reported annually to the New York Department of Environmental Conservation. Detailed pesticide use data are available in New York through a written request to the New York Department of Environmental Conservation. Brief annual summaries of the data are available at the following website: http://www.dec.ny.gov/chemical/27506.html.

Since 1990 in California, growers, commercial pest control operators, and professional gardeners must submit monthly reports on all pesticides that they use. The reported information must include the date and location of the application, the kind and amount of pesticide used, and the type of commodity if the pesticide was used on a crop. These data have been used to identify risk factors associated with illness from restricted-use organophosphate pesticides in an agricultural setting (Weinbaum *et al.*, 1997) and were utilized to find that Parkinson's disease mortality was higher in those counties where agricultural pesticides were used (Ritz and Yu, 2000). The CDPR collects and maintains the pesticide use data, but the Pesticides Action Network of North American website provides easy and convenient access to the data (see http://www.pesticideinfo.org/Search_Use.jsp).

Problems have arisen with denominators derived from pesticide use databases. Among these are the lack of information on the number of exposed workers and their duration and intensity of exposure. In addition, care must be taken when using total poundage as the denominator. Pesticides applied at low rates may exhibit exaggerated risk if the time required for application is similar to or greater than the length of time to apply high-rate pesticides.

When evaluating rates of pesticide-related illness, it is important to be mindful of the various factors that can influence the data. These include the methods used to approximate the person–time at risk, the inherent toxicity of the pesticide, the method of application, the amount applied, the equipment used, and the skills of the applicators. Any analyses that compare groups based on only some of these factors make the implicit assumption that the groups do not differ with respect to the other factors.

Generalizing rates of poisoning to those outside the population that was investigated can be problematic. For example, the risks among fieldworkers can vary depending on the crops they tend, the tasks they perform, climatic conditions, and their individual work practices. The most difficult factors to ascertain may be the most critical. Ideally, changes in fieldworker tasks and practices over the time interval of interest should be determined. As such, when generalizing surveillance data on pesticide-related illness, the amounts of pesticide used or number of acres treated may not be adequate to assess the true risks that were experienced by fieldworkers.

61.6.2 Limitations Related to Definitions

Enumerating the population at risk is not the only problem in interpreting surveillance data. When using surveillance data or comparing data from various surveillance systems, it is extremely important to understand the case definition that was used. Different pesticide poisoning surveillance systems may assign different meanings to the terms "pesticide," "exposure," "case," and "related."

In the United States, FIFRA defines pesticides to include "all substances and mixtures of substances" that "prevent, destroy, repel, or mitigate" any pest (7USC§136). Other statutes clarify that pests include all deleterious organisms, even bacteria and viruses. Pesticides consequently include sanitizers and disinfectants (e.g., chlorine) along with moth balls, rat baits, herbicides, fumigants, and many other substances. Few programs attempt to track the effects of all these products. Most surveillance systems track illnesses and injuries associated with exposure to insecticides, fungicides, rodenticides, fumigants, and herbicides. Health effects from exposures to other pesticide products such as disinfectants and antibacterials are not universally included in surveillance systems.

Each surveillance system sets its own threshold for the types of cases that are captured. Some systems attempt to identify only cases that resulted in medical consultation or only those that included hospitalization. Other data sources accept self-reports of illness or injury. Even when systems use the same objective standard, such as hospitalization, criteria for hospital admission may vary with culture, geography, time period, and economic circumstances.

Additional discrepancies stem from variations in criteria for what constitutes pesticide-related illness and injury. Some have argued that surveillance should consider only those intoxications in which the pesticide acts on human victims by the same mechanism by which it controls pests (i.e., cholinesterase inhibition for organophosphate pesticides). Some critics have also taken issue with inclusion of health effects that may be related to the "inert" (nonpesticidal) ingredients in a pesticide product. Public health surveillance more typically considers all characteristics of pesticide products that can cause harm. These surveillance systems record illness and injury resulting from exposure to the pesticide products (i.e., the formulated product, not just the active pesticide ingredient). In addition, these surveillance systems record burns or smoke inhalation from pesticide fires, traumatic injuries from pesticide explosions, illnesses resulting from purposeful (i.e., homicidal or suicidal) and unintentional ingestion, allergic reactions to pesticide products, and effects associated with inert ingredients. They may even record reactions to a pesticide's noxious odor.

Evaluation of the causal relationship between pesticide exposure and adverse health effects is complicated. Some surveillance systems accept the clinician's diagnosis in determining the relationship, whereas other systems have more complex case definitions and classification schemes. It is useful for surveillance systems to independently examine the relationship between exposure and health effects because the clinical diagnosis may not be correct (e.g., the health care professional may report illnesses suspected to be pesticide related but that are later found by surveillance staff to be unrelated to pesticide exposure). Surveillance systems that examine the relationship between exposure and health effects must take several factors into account, including the wide range of symptoms various pesticides can produce, the nonspecific nature of reported signs and symptoms (especially in less severe illness), limited or nonexistent analytical environmental data on the individual's exposure, lack of clinical/biological measures of pesticide absorption, and inappropriate use of available tests. Evaluating anxiety poses a particular problem because many common insecticides are neurotoxic and may elicit anxiety through pharmacologic mechanisms; on the other hand, anxiety unaccompanied by pesticide exposure often mimics toxic effects. Rarely can physical findings or test results clarify this issue. In response to these difficulties, pesticide surveillance systems typically classify cases into one of several categories that reflect the certainty of the relationship between exposure and illness (see Section 61.5).

When examining surveillance data, care must be taken not to confuse reports with confirmed cases. This is especially true for surveillance systems that include reports from affected individuals and nonmedical personnel and where no investigation is undertaken to follow up the report. Following an appropriate investigation, surveillance systems that use the NPHSS case definition classify reports of illness into one of the following categories: "confirmed" (i.e., defined as definite, probable, and possible cases),

"nonconfirmed" (i.e., defined as unlikely cases, those determined not to be a case, and those where insufficient information is available), or "suspicious" (i.e., insufficient toxicologic information is available to determine whether a causal relationship exists between the exposure and the health effect). Some might argue that including case reports that are unconfirmed or have a lower degree of certainty compensates for underreporting. However, this may not be an appropriate remedy for underreporting because the unconfirmed cases may not be representative of the undetected true cases.

61.6.3 Limitations Related to Sensitivity

No surveillance system succeeds in identifying every event of interest. Most surveillance systems capture 5–80% of cases that occur (Cates and Williamson, 1994). It should be recalled that even surveillance system data without high sensitivity can be useful for monitoring trends as long as the sensitivity remains relatively constant. The likelihood that a case of pesticide-related illness will be reported may vary with occupation, social status, the circumstances of exposure, and even the individual pesticide. Surveillance systems that rely on a variety of sources for case ascertainment are likely to be more representative of the universe of cases.

Physician reporting, usually indirectly through workers' compensation systems or poison control centers, is one of the most common mechanisms for surveillance. This method is the mainstay of many communicable disease reporting systems, but it is not necessarily the most effective method for surveillance of pesticide poisoning. Physician reporting requires that the affected individual seeks medical care, that a diagnosis of pesticide-related illness or injury is made or suspected, and that the physician reports the suspected case to public health authorities. Barriers exist at each of these steps that can hamper physician reporting. For example, some populations at greatest risk for pesticide exposure are likely to seek medical attention only for moderate or high severity illness. Those ill individuals who do not seek health care may be detected by surveillance systems based on physician reports only after an investigation into a sentinel case involving a poisoned co-worker or family member who sought medical care. Furthermore, pesticide-related illness is not routinely encountered by a majority of primary care providers in the United States, and most receive minimal training on recognition of environmental or occupational illness (Institute of Medicine, 1988; Pope and Rall, 1995; Schenk *et al.*, 1996). In addition, the ability to make the diagnosis is complicated by the fact that symptoms are often nonspecific, and by the lack of readily available urine or blood tests to measure the pesticide, its metabolites, or the effects of the pesticide. Even when tests are available, they are frequently not performed, are used inappropriately (e.g., measuring cholinesterase depression after exposure to a pyrethroid insecticide), or are not performed sufficiently promptly to detect the abnormality. This problem of recognition is found in industrialized and developing countries alike (Keifer *et al.*, 1996).

Once the diagnosis of pesticide poisoning is made, there are many reasons for failing to report it. Despite broadly worded reporting guidelines, physicians are often reluctant to report cases that they believe are unconfirmed clinically. Additional barriers to physician reporting include protection of a patient who fears job loss, ignorance regarding the reporting requirement, and concerns that reporting a case may disrupt the personal relationship between the physician and the employer. Cultural pressures to downplay the hazards of pesticides and perceptions that registered pesticides are unlikely to cause illness may prevent a physician from reporting cases.

61.6.4 Legitimate uses for Surveillance Data

With so many difficulties and limitations, surveillance of pesticide-related conditions may seem futile. However, even problematic surveillance data can advance public health when used with appropriate caution. Surveillance data have been useful for identifying emerging pesticide hazards and new populations at risk. When these emerging problems are identified, they present an opportunity to implement interventions that will prevent subsequent illness. For example, the identification of several California grape harvesters who became ill after exposure to phosalone led directly to the withdrawal of this pesticide. Although phosalone had been in use for nearly 20 years on crops that require minimal to moderate hand labor activity, it was eliminated only after it began to be used more widely on grapes, a crop requiring more extensive hand labor activity. This problem was detected when the ill grape harvesters were identified using surveillance data (O'Malley and McCurdy, 1990). A similar scenario was repeated in 1993 in Washington when 26 workers at 19 orchards became ill during a period of several months. The outbreak and the ensuing investigation resulted in the suspension, and eventual withdrawal, of mevinphos use in Washington apple and pear orchards (CDC, 1994; Washington State Department of Agriculture, 1994). Another example involves surveillance data from Florida that resulted in identification of illnesses associated with efforts to control Mediterranean fruit fly (medfly) infestations (CDC, 1999a). Medfly is an insect that can damage more than 250 fruit and vegetable plant species, and it is a serious threat to the agricultural industry. In the spring and summer of 1998, aerial applications of malathion combined with a corn protein bait were used by federal and state agriculture authorities to eradicate medfly infestations detected in portions of four Florida counties. A total

of 123 acute pesticide-related illness cases associated with exposure to the pesticide used in the eradication effort were identified, representing a crude rate of 9 cases per 10,000 residents in the exposed areas. Following publication of these findings, the U.S. and Florida Departments of Agriculture adopted procedures to control medfly without the use of pesticides. These methods included more rapid detection of medfly infestations and the release of sterile male medflies to interrupt the reproductive cycle. To our knowledge, there have since been no medfly infestations in the United States that required aerial pesticide application for control. These situations exemplify the public health importance of prompt health care provider reporting and appropriate public health agency follow-up. Although surveillance that includes active case follow-up is resource intensive, it provides the opportunity to gather information that can be used to develop strategies for prevention. The information obtained through case follow-up is often more difficult to obtain or not available when cases are identified retrospectively through review of existing data sources (e.g., hospital discharge records). This is because long latency between a poisoning event and investigation makes locating the case more difficult, especially if the case is transient; can compromise the memory of events by those familiar with the poisoning incident; and can preclude an environmental investigation to identify residues or collateral damage because these will have vanished.

Better surveillance likely would have reduced the health and financial costs associated with the indoor use of methyl parathion. From 1984 to at least 1997, homes and businesses in at least five different states were illegally sprayed with methyl parathion (Figure 61.10). Unfortunately, corrective action was not enacted until 1997. These events occurred in New York, Ohio, Michigan, Mississippi, and Illinois, resulting in expensive relocation and remediation activities. Relocations have involved more than 1500 individuals. The estimated cleanup costs for these incidents were more than $90 million (U.S. EPA, 1997a). Little information is available on the health effects associated with these incidents. However, one published report described methyl parathion-related illness among seven siblings, two of whom had a fatal outcome (CDC, 1984). In addition, another government report that summarized the 1995 Ohio investigations found that 20% or more of respondents reported symptoms during the 2 weeks following methyl parathion application (NCEH, 1996). These investigations also found that 20 of 50 (40%) indoor pet animals present in these homes died within 2 weeks of methyl parathion application (pointing out the value of pets as sentinels of human exposure and illness). To prevent additional exposure incidents, a memorandum of agreement between the U.S. EPA and the manufacturers of emulsifiable methyl parathion concentrate became effective in January 1997. The agreement included recall of particular products, changes in packaging and labeling, as well as the addition of an odor-producing agent (U.S. EPA, 1997b). Because the problem with methyl parathion has existed since at least 1984 in several different states, a national surveillance system with active case follow-up may have resulted in a more timely identification of the magnitude of this problem and earlier adoption of preventive and regulatory measures.

FIGURE 61.10 Worker conducting methyl parathion remediation to a dwelling in Mississippi (courtesy of U.S. EPA).

Surveillance data can also be a source of cases for formal epidemiologic studies. Important morbidity and mortality studies can be designed that involve a cohort of individuals poisoned by a specific pesticide or group of pesticides. For example, Steenland *et al.* (1994) examined a group of workers who had a history of acute organophosphate insecticide poisoning to determine if these workers had chronic neurologic sequela. The workers in this study were identified using surveillance data collected by the California EPA.

As noted previously, surveillance data can also be used to examine the magnitude of pesticide-related illness and to assess trends. Data from several different surveillance systems have been combined to provide a more comprehensive estimate of the magnitude of pesticide-related illness and injury. For example, data from AAPCC, SENSOR-Pesticides, and CDPR were combined to assess the magnitude and trends of pesticide poisoning among working youth (Calvert *et al.*, 2003), the adverse effects of automatic insecticide dispensers (CDC, 2000), and illnesses associated with pesticide exposures at schools (Alarcon *et al.*, 2005).

61.6.5 Mechanisms to Strengthen the Surveillance of Acute Pesticide-Related Illness

Some very specific actions can be taken to enhance existing surveillance systems. Some of the changes have been underway for several years, and an evaluation of their efficacy should be possible.

FIGURE 61.11 A scout uses the "white pan beat method" to check strawberries for insects (courtesy of California EPA).

One important action is the need to improve training of primary health care professionals. The U.S. EPA launched an initiative to target health care professionals with educational and training opportunities on pesticide-related health issues (Lindell *et al.*, 2003a,b; National Environmental Education and Training Foundation, 2002). This initiative involves strategies to ensure that primary health care professionals can recognize health effects from pesticide exposure. It includes mechanisms to enhance their abilities to diagnose illness and manage exposures, engage in preventive management (at the case and community level), appropriately report exposures and illnesses to public health authorities, and access appropriate resources when necessary. To foster success, these activities should be coupled with education of workers and consumers on many of these same topics. The public should be warned about pesticide dangers through broad media campaigns that explain the importance of reading and understanding the pesticide label, using pesticides sparingly in conjunction with implementation of an integrated pest management plan (Blessing, 2001), and taking necessary precautions (e.g., using protective equipment such as chemical-resistant gloves) (Figure 61.11). Also, pesticide labels should be improved to make information easier to find and understand.

Increasing the quality and availability of biological monitoring tools would aid surveillance by assisting with confirmation of cases. The development of new biomarkers of exposure and health effects is also an extremely important area that would enhance surveillance data. Reliable and affordable screening methods for field and clinical settings must be available if they are to be used routinely in developing countries and under the constraints of managed health care systems. Most pesticide biological markers are still primarily research tools, and analyses are conducted only at specialized centers (e.g., CDC Environmental Health Laboratory and NCEH). Even cholinesterase monitoring, the most commonly used measure of biological effects from exposure to organophosphate and carbamate insecticides, suffers from lack of standardization. Both the handling of specimens and the assay method require standardization to obtain valid test results (Wilson *et al.*, 1996, 2004). Although much progress has been made in delineating these problems, they have not been satisfactorily resolved (Wilson *et al.*, 2005).

The ability to provide summary data and direct feedback to the medical community, agricultural workers, pesticide manufacturers, commercial pest control firms, and policy makers is a critical aspect of surveillance. Although existing surveillance systems have communicated their findings in several publications, more can be done to share surveillance findings with various stakeholders, including partner government agencies, public interest groups (e.g., environmental groups and public health organizations),

agricultural employers, pesticide manufacturers, the pest control industry, and worker advocacy groups (e.g., unions). In addition, the ability to aggregate data across states, combined with increased dissemination of information, has resulted in a better understanding of the extent and nature of acute pesticide-related illness and injury. However, this is also an area in which improvements can be made that will strengthen surveillance.

If a pesticide poisoning surveillance program does not have a statutorily mandated multiagency oversight committee (or board) to address pesticide use and hazards, the program might benefit from developing an advisory committee. Members can include stakeholder representatives as described in the previous paragraph. Advisory committee meetings, which should occur two to four times per year, are often a source of valuable ideas for the program. They also provide the pesticide poisoning surveillance program an opportunity to maintain contact with various constituencies, apprize them of findings, develop joint programs for outreach and intervention, and discuss mechanisms for improving reporting and investigation.

Lack of access to health care may be an important barrier to identifying acute pesticide-related illness among individuals with low incomes, including agricultural workers and their families. The most obvious solution would be to improve access to health care. Because farm workers are at greatest risk of acute pesticide poisoning (Calvert *et al.*, 2008), a periodic survey of the farm worker population would be useful to assess the magnitude and trend of pesticide poisoning in this population. One approach would be to piggy-back onto NAWS (see Section 61.2.9). In 1999, NAWS included questions to determine the magnitude of pesticide poisoning among crop workers. To our knowledge, neither these nor similar questions to assess the incidence of pesticide poisoning were included in NAWS surveys before or after 1999.

61.7 FUNDAMENTALS OF EPIDEMIOLOGY

When conducting surveillance of pesticide-related disease and injury, a decision must be made as to whether the pesticide exposure caused the documented illness. Epidemiologic studies are often the source of information used to make these decisions. Therefore, although the emphasis of this chapter is on surveillance, we think it is important to describe the basic principles of epidemiology and the role of epidemiology for identifying health effects related to pesticide exposure. It is useful to begin by defining epidemiology. Epidemiology is the study of the distribution and determinants of disease in human populations. Epidemiologic studies compare the rates of disease in populations exposed to various risk factors to the rates in populations that are not exposed. Such comparisons evaluate what factors may cause or influence disease.

61.7.1 Principles of Epidemiology

A major premise of epidemiology is that disease is not simply a random occurrence but, rather, is the result of various causal factors (Checkoway *et al.*, 1989). These causal or risk factors influence the distribution of disease in a population. Differences in disease patterns may be explained by differential distribution of risk factors between populations. These causal or risk factors include age; sex; race or ethnicity; genetic susceptibility; personal lifestyle factors such as smoking habit, diet, exercise, use of drugs, and weight; and occupational or environmental exposure to various chemical and physical agents.

Diseases caused by occupational or environmental exposures may be either acute or chronic. Acute diseases occur soon after an exposure, whereas chronic diseases develop many years after exposure. Examples of acute disease are leukopenia caused by acute radiation poisoning and eye and upper respiratory irritation caused by sulfur dioxide or ozone. Examples of chronic disease include pneumoconiosis caused by crystalline silica or coal dust and asthma caused by isocyanates. The time period between initial exposure to a causal agent and disease detection can be divided between the induction period – time between causal action and disease initiation – and latency period – time between disease initiation and detection. The longer the induction–latent period, the more difficult it is to link causal factors to the disease outcome. Pesticides are known to cause both acute diseases, such as systemic poisonings and skin rashes, and chronic diseases, such as cancer, lung disease, neurotoxicity, and reproductive problems (Alavanja *et al.*, 2004).

61.7.2 Epidemiologic Study Designs

When studying the health effects of occupational and environmental exposures, epidemiologists are very rarely able to control the exposures administered to study subjects, such as in a randomized controlled trial of a pharmaceutical. Therefore, epidemiology of occupational and environmental exposures is largely an observational science, relegated to documenting the past and present risk factors and evaluating the association between these risk factors and disease status (Kleinbaum *et al.*, 1982).

Epidemiological research begins with a hypothesis to be tested. For example, it may be hypothesized that farmers with a history of applying insecticides to their crops have a greater risk of developing cancer than the general population. The epidemiologist then designs a study to test this hypothesis. The epidemiologist may choose from among the following types of observational (nonrandomized) study designs. For a fuller discussion on these study designs and their interpretations, the reader is referred to standard epidemiologic textbooks (Kleinbaum *et al.*, 1982; Rothman *et al.*, 2008).

(a) Cohort Study

Cohort studies begin with enumeration of a population (the cohort) that shares common characteristics or risk factors (e.g., exposures). The cohort's health experience is then evaluated over a defined time period. The following is the basic question addressed by a cohort study: Are those with exposure more (or less) likely to develop disease compared to those who are unexposed? The control or reference populations are generally national or regional (i.e., state or province) populations, which provide generally stable disease rates.

Cohorts can be enumerated in present time and then followed forward in time. This approach is termed a prospective cohort study. As the cohort is followed through time, the exposures and diseases of the individual cohort members are documented. The rates of disease among individuals with specific exposures of interest are compared to the rates of disease among unexposed or low exposed members or an unexposed reference population. Another type of cohort study is the retrospective cohort study, which is also referred to as a historical cohort study. In this type of study, a cohort is enumerated in the past (i.e., a cohort that began exposure at some point in the past) and followed up to the present to identify those individuals who developed disease. The disease rates in the cohort are compared to those occurring in an unexposed comparison population.

An example of a prospective cohort study is the Agricultural Health Study (AHS), which was begun in 1994. The AHS is being conducted in Iowa and North Carolina by the National Cancer Institute, the National Institute for Environmental Health Sciences (NIEHS), the U.S. EPA, and NIOSH (Alavanja *et al.*, 1996). It consists of 57,311 licensed restricted-use pesticide applicators and 32,347 of their spouses. The AHS participants are asked to answer questionnaires about their lifestyle, work practices, and exposures at approximately 5-year intervals in an attempt to relate exposure to disease outcomes. The participants are also matched to vital records systems and cancer registries to identify causes of death and cancer incidence, respectively. Disease rates are determined at regular intervals, and potential risk factors are assessed by the information collected on the questionnaires and contained in disease registry records. An internal reference population is usually used that consists of the unexposed or low-exposed portion of the AHS cohort. This study has been prolific in generating important findings, including associations between carbofuran and lung cancer (Bonner *et al.*, 2005), alachlor and lymphohematopoietic cancers (Lee *et al.*, 2004), and diazinon and lung caner and leukemia (Freeman *et al.*, 2005).

An example of a retrospective cohort study is provided by a study of 20,245 agricultural pesticide applicators in Sweden (Wiklund *et al.*, 1989). It also evaluated the association between pesticide exposures and disease. The cohort, consisting of all applicators who had been licensed between 1965 and 1976, was followed in the Swedish Cancer Register from the date they received their license until 1982 or their death if it occurred before 1982. The number of cancer cases in the applicator cohort was compared to the number of cases occurring in 5-year age and sex groups during the same time period in the whole Swedish population. The age-, sex-, and time period-adjusted number of cancer cases in the Swedish population represent the number of cases that would be expected in the pesticide applicator population. A total of 558 malignant tumors were found among Swedish pesticide applicators compared with 649.8 expected cases, resulting in a statistically significantly decreased standardized incidence ratio of 0.86. A finding that reaches statistical significance implies that the finding is unlikely to be due to chance. No cancer rates among the Swedish pesticide applicators were found to be significantly increased, although they had higher rates for testicular cancer, Hodgkin's disease, and tumors of the nervous system and endocrine glands.

Cohort studies have several strengths. They provide information on the time lag between the first known exposure and disease detection, and they can be used to evaluate risk for many different diseases. They also measure exposure before disease occurs, resulting in less recall bias by study subjects. However, cohort studies are costly, requiring long-term commitments of time and resources and a large sample size. In addition, they are ill-suited for studying rare diseases. Furthermore, a cohort study may not be possible if data for enumerating and following up the cohort are incomplete. Retrospective cohort studies are usually restricted to investigating fatal diseases because nonfatal diseases (with the exception of cancer and end-stage renal disease) are often not recorded historically. In contrast, prospective cohort studies may document nonfatal diseases as they occur. The primary cost for conducting cohort studies often involves obtaining exposure data on a large number of subjects, of which only a small proportion develop the disease of interest.

(b) Case–Control Study

The following is the basic question addressed by the case–control study: Are the people with existing disease more or less likely to have been exposed than those without the disease? The distinguishing feature of case-control studies is that subjects are selected based on their disease status, reducing cost by limiting exposure assessment to only cases of the disease of interest and a control group. Case–control studies are particularly useful for studying rare diseases or diseases with a long latency since first exposure. Cases may be identified from disease registries, hospital or clinical records, or volunteers. Controls are selected to be similar to the cases with exception of disease status and are often matched to cases by age, gender, race, and residence.

Exposure information is obtained either from existing records or from a detailed self-reported questionnaire. This information is used to compare the exposure prevalence between the cases and controls.

An example of a case–control study to evaluate the association between pesticide exposure and disease is provided by a study of childhood brain cancer in four Atlantic coast states (Shim *et al.*, 2009). All cases of brain cancer were diagnosed when the children were younger than 10 years of age, between the years 1993 and 1997, and were identified from statewide cancer registries in four states (i.e., Florida, New Jersey, New York, and Pennsylvania). Each case was matched to one control through telephone calls using random-digit dialing (Waksberg, 1978). Controls were individually matched to cases by age (within 1 year of the birth year), sex, race, and state of residence. The mothers of the cases and controls were interviewed via a computer-assisted telephone system over 13 months between 2000 and 2001. The questionnaire obtained, among other things, information on maternal and paternal residential and occupational pesticide exposures during the 2 years before the child's birth. Analyses were separately performed for astrocytoma and primitive neuroectodermal tumors (PNET), the two most common types of childhood brain cancer. Residential herbicide use was associated with a significantly increased risk for astrocytoma (odds ratio (OR), 1.9; 95% confidence interval, 1.2–3.0), as was residential and occupational use of herbicides by the father (OR, 1.8; 95%CI, 1.1–3.1). PNET was not found to be associated with pesticide exposure.

Case–control studies are relatively inexpensive because they involve fewer subjects than cohort studies and can be completed in a relatively short time. However, the information collected on exposures occurs after the disease has been diagnosed, which may make diseased people more (or less) likely to remember previous exposures (recall bias). Also, diseased individuals may be more motivated to participate in a case–control study than a healthy control (selection bias).

(c) Cross-sectional Study

In a cross-sectional study, exposure and disease are evaluated at the same time. The prevalence of disease is measured in a defined population at a particular point in time, whereas the exposures of the individuals are also measured at that time and retrospectively. For example, the rate of occurrence of symptoms in workers exposed to a particular pesticide would be compared to the rate in workers who were unexposed. Cross-sectional studies are suitable for evaluating nonfatal diseases or measuring physiologic responses to workplace exposures. Data are collected using clinical examinations, symptom surveys, or direct biological or physical measurements. A critical problem with the cross-sectional design is the "chicken or the egg" conundrum – that is, did the exposure influence the disease or vice versa. Also, cross-sectional studies may miss many diseases of short duration. Because cross-sectional studies typically only include currently employed workers, retirees or other workers who terminated employment because of ill health, possibly attributable to their exposures, are not studied. Exclusion of these former workers may bias the study findings toward the null because these former workers may be the most relevant subjects for investigating delayed or progressive health outcomes.

An example of a cross-sectional study is one that was used to evaluate the association between fumigant exposure and disease among structural fumigation workers in Florida (Calvert *et al.*, 1998). In this study, 123 structural fumigation workers and 120 unexposed controls were interviewed and examined. Nerve conduction, vibration, neurobehavioral, olfactory, visual, and renal function testing was conducted. The median lifetime duration of methyl bromide and sulfuryl fluoride exposure among workers was 1.20 and 2.85 years, respectively. Sulfuryl fluoride exposure over the year preceding examination was found to be associated with significantly reduced performance on one cognitive test and on olfactory testing. In addition, fumigation workers had significantly reduced dexterity of the dominant hand. A nonsignificantly higher prevalence of carpal tunnel syndrome was also observed among the fumigation workers. The authors concluded that occupational sulfuryl fluoride exposures may be associated with subclinical effects on the central nervous system, including effects on olfactory and some cognitive functions. However, no widespread pattern of cognitive deficits was observed. The peripheral nerve effects were likely due to ergonomic stresses experienced by the fumigation workers.

(d) Ecologic Study

Perhaps the crudest approach to evaluating exposure–disease associations is the ecologic study. In this type of study, disease rates are compared between geographic areas rated according to their estimated extent of exposure. The units of exposure correspond to geographical areas rather than individuals.

An example of an ecologic study is one used to evaluate the association between cancer and dibromochlorpropane (DBCP) contamination in Fresno County, California, drinking water (Wong *et al.*, 1989). All cases of gastric cancer and leukemia cases occurring between 1960 and 1983 in Fresno County were identified by the California Vital Statistics office. The cancer rates were calculated using the 1960, 1970, and 1980 census data stratified by age, sex, and race. The cancer rates were compared by areas in the county stratified by the concentration of DBCP found in drinking water. No correlation was found between gastric cancer and leukemia mortality rates and DBCP concentrations.

Ecologic studies use readily available data that have been collected for other purposes, and they can be done

relatively quickly. However, ecologic studies are severely limited because they do not associate exposure to individuals. They suffer from the "ecological bias" (Wakefield, 2008) that states that conclusions regarding individual risk on the basis of group risk must be made cautiously because risk factors at the individual level have not been collected. Ecologic studies do not control for other exposures (confounding) that may be associated with the disease of interest, and they can be significantly influenced by the migration of individuals into or out of the geographic area (selective migration). Although ecologic studies do not provide firm conclusions about the association between exposures and disease, they are used for generating hypotheses and to guide future, more in-depth research.

(e) Case Reports and Case Series

These consist of a report of a medical diagnosis among an individual or series of individuals with exposures not previously thought to be associated with that disease. Sometimes these are referred to as disease clusters. These can be particularly informative when the disease is rare and when etiologic factors are unknown. Like cross-sectional studies, case reports and case series provide little information on cause and effect. However, they are important sentinels that alert epidemiologists of suspected disease–exposure relationships that require more in-depth epidemiologic investigation.

An example of a case report is an account of a birth defects cluster involving three infants born within 8 weeks of each other to pesticide-exposed migrant farm workers employed in North Carolina and Florida (Calvert *et al.*, 2007a). During the period of organogenesis (approximately days 14–59 after fertilization) when birth defects are most likely to occur, all three mothers appear to have unknowingly worked in tomato fields that were under a restricted entry interval because the fields were recently treated with pesticides, some of which have been shown to be animal teratogens. One infant was born with tetramelia (the absence of all four limbs). The second infant was born with mild Pierre Robin syndrome (micrognathia, high arched palate, and mild persistent palatine rugae). The third infant died at 3 days of age with multiple severe malformations, including cleft lip and palate, imperforate anus, solitary kidney, vertebral anomalies, dysplastic low-set ears, and ambiguous genitalia. These findings were reminiscent of a severe type of the Goldenhar syndrome (also referred to as oculoauriculovertebral sequence). The cluster was investigated by NIOSH and public health authorities in Florida and North Carolina. It was concluded that the available evidence was inadequate to establish a causal relationship between the birth defects and pesticide exposures. However, this cluster pointed to the need to better protect farm workers from pesticide exposures. In addition, following the cluster investigation, lawmakers in North Carolina enacted legislation to broaden the coverage of antiretaliation rules to include agricultural workers; increased recordkeeping requirements pertaining to pesticide applications; and funded various activities to prevent harm from pesticides, including strengthening surveillance, improving the quality of pesticide compliance inspections, and increasing and improving pesticide safety training (Calvert and Higgins, 2009).

Disease clusters can be misleading. Occurrences of rare disease are expected to be distributed randomly. Random distributions can include clusters of disease. As such, one needs to remember that case series or disease clusters can occur randomly, and such clusters may not be indicative of an association with a hazardous exposure.

61.7.3 Evaluating Pesticide Health Information

Information on the toxicity of pesticides can be found in textbooks, journal articles, and from information provided by pesticide producers. Each of these sources may be valuable, but each may also have particular bias. When relevant information is identified, one must decide whether to trust the information and whether the information can be generalized to new cases identified through surveillance. In many medical disciplines, information relevant to a particular question may be summarized in systematic reviews that provide valid conclusions. Unfortunately, such reviews are uncommon with respect to the health effects associated with specific pesticide products or active ingredients. As such, skill is needed both to efficiently search the literature for relevant information and to interpret the validity of any information that is discovered.

There are several approaches for identifying relevant literature. These include asking knowledgeable colleagues (and pesticide producers), reviewing references cited in textbooks, or using an electronic bibliographic database such as PubMed. The limitation of asking colleagues and using textbooks is that these sources may not be up-to-date. The most up-to-date source of relevant information is obtained by searching PubMed. Accessing this database has become a basic and easily acquired skill. There is no charge for accessing this database through the National Library of Medicine (http://www.ncbi.nlm.nih.gov/pubmed).

Assessing the validity of a study can be more complicated (Levine *et al.*, 1994). In cohort and cross-sectional studies, it is important that the exposed and control groups are similar with respect to all factors that may affect the outcome, with the exception that the exposed group has the exposure of interest. Practically, this means that both groups should be similar in age, gender, race, socioeconomic status, cultural background, and social habits (e.g., smoking and alcohol consumption). The study investigators should demonstrate that these characteristics are comparable or use statistical techniques to adjust for

differences. In a case–control study, it is important that the cases with the disease of interest and the unaffected controls are similar with respect to important determinants of the disease of interest. In addition, controls should be randomly drawn from the same population from which cases were drawn (i.e., controls should have similar opportunity for exposure). For example, in a case–control study examining the association between pesticide exposure and cancer, it would be inappropriate to have the control group consist entirely of white-collar professionals because of their minimal opportunity for pesticide exposure. Even when investigators take appropriate precaution to ensure comparability for known risk factors, there may be a pronounced imbalance in the distribution of risk factors that are unknown to the investigators. It may be these unknown and unmeasured risk factors that are responsible for any observed findings.

Other factors to consider when assessing the conclusions of an observational study include assessing the temporal sequence of events. It is important that the investigators document that the exposure preceded the disease or outcome of interest. It is also important to observe a dose–response relationship. Attributing a particular outcome to a pesticide exposure can be made with more confidence if risk of the outcome increases with increasing cumulative, intensity, or duration of exposure. It is also important to ensure that the investigators minimized bias in the collection of data (e.g., blinding data collectors and study subjects to the study hypotheses). The magnitude of the risk can also be helpful in assessing the validity of a study. With very large values of risk, one may be more confident that bias or uncontrolled risk factors are not responsible for the outcome.

Note that none of the conditions described in this section are either necessary (with the exception of temporal sequence) or sufficient to prove that a causal association exists between an exposure and an illness. The topic of causality is complex and is not discussed further. An excellent review of this topic can be found elsewhere (Rothman *et al.*, 2008).

61.8 INTERNET AND TELEPHONE RESOURCES FOR PESTICIDE INFORMATION

Important sources of pesticide information are readily available on the Internet. Some Internet sites that are useful for pesticide-related illness and injury surveillance follow.

(a) Agricultural Health Study

This is a large prospective cohort study consisting of 57,311 licensed restricted-use pesticide applicators and 32,347 of their spouses. The AHS is being conducted in Iowa and North Carolina by the National Cancer Institute, NIEHS, the U.S. EPA, and NIOSH. This study is an important source of information on illnesses and their association with pesticide exposures. The website has information on the study design, important findings from the study, and guidelines for initiating research collaboration with the AHS (http://aghealth.nci.nih.gov/index.html).

(b) Bureau of Labor Statistics

This site contains pesticide illness tabulations that supplement those provided in the BLS annual reports. Information is available only for pesticide illnesses that result in lost worktime. The website address is http://www.bls.gov/iif.

(c) California Environmental Protection Agency

This site is a source for consumer fact sheets and provides access to several useful databases (e.g., a pesticide use in California database, a pesticide product database, a chemical ingredient database, a company information database, and a California pesticide illness query). The site also has links to the Pesticide Illness Surveillance Program. The website address is http://www.cdpr.ca.gov.

(d) Extoxnet

This is an excellent resource for information on specific pesticides. In includes a useful search engine. This site is a cooperative effort of the University of California–Davis, Oregon State University, Michigan State University, Cornell University, and the University of Idaho. The website address is http://ace.orst.edu/info/extoxnet/ghindex.html.

(e) National Agricultural Statistics Service, U.S. Department of Agriculture

This site provides information on agricultural pesticide usage. The website address is http://www.nass.usda.gov.

(f) National Institute for Occupational Safety and Health

NIOSH is the federal agency responsible for conducting research on occupational disease and injury. Its pesticide illness and injury surveillance topic page contains a wealth of useful information, including a guide on initiating and maintaining a state-based pesticide poisoning surveillance program (http://www.cdc.gov/niosh/docs/2006-102). This site also has information on the SENSOR-Pesticides program, including its case definition, standardized variables, fact sheets, a pesticide illness database, and summaries of surveillance findings. Its pesticide illness and injury surveillance topic page can be found at http://www.cdc.gov/niosh/topics/pesticides.

(g) National Pesticide Information Center

This is a cooperative effort of Oregon State University and the U.S. EPA. It offers a toll-free telephone service that provides information about pesticides and pesticide-related topics (1-800-858-7378). At its website, one can find fact sheets, information on current pesticide topics, podcasts, and web links to various pesticide-related topics (http://npic.orst.edu).

(h) Pesticides and Epidemiology: Unraveling Disease Patterns

This is a useful primer intended to facilitate the understanding of basic epidemiological concepts and methods. Such an understanding will enable appreciation of scientific reports that explore associations between diseases and pesticide exposures. This primer is available at http://www.btny.purdue.edu/Pubs/PPP/PPP-43.pdf.

(i) PubMed

The medical literature can be searched for information on specific pesticides. Searches on this site are free-of-charge. The website for PubMed is http://www.ncbi.nlm.nih.gov/pubmed.

(j) University of Nebraska–Lincoln Institute of Agriculture and Natural Resources

This website contains an extensive listing of links on pesticide-related topics. The links are grouped into several categories, including environmental protection, pesticide licensing, pesticide labels and MSDS, pest management, and health protection and safety. The website for these pesticide-related links is http://pested.unl.edu/pesticide/pages/index.jsp.

(k) U.S. Environmental Protection Agency

This site contains a large amount of information, including consumer fact sheets, information on pesticide regulations, and pesticide product information. The website is http://www.epa.gov/pesticides. Pesticide product information can be found at http://www.epa.gov/opppmsd1/PPISdata/index.html. The manual titled "Recognition and Management of Pesticide Poisonings" is available at http://www.epa.gov/oppfead1/safety/healthcare/handbook/handbook.htm. An update of this manual is in preparation.

CONCLUSION

A comprehensive, national surveillance system for acute pesticide-related illness and injury does not currently exist. However, this chapter describes several surveillance systems for pesticide-related illness and injury, each having strengths and weaknesses. Some systems, such as the NPDS, are most useful for assessing magnitude and trends. Others (e.g., state-based surveillance systems) are more useful for timely identification of outbreaks and emerging problems. Efforts to standardize data collection have been ongoing. Standardization of data collection facilitates linkage of data across surveillance systems to create a fuller understanding of the acute pesticide-related illness and injury problem. Through standardization and information sharing across surveillance systems, a national comprehensive surveillance system may be attainable. Although all of the surveillance systems described in this chapter have strengths and weaknesses, almost all provide useful information that is vital to target scarce public health resources toward the prevention of pesticide-related effects on human health and the environment.

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