CHAPTER

# 27

# Surveillance of Pesticide-Related Illness and Injury in Humans*

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## 27.1 INTRODUCTION

A simple concise definition for surveillance is "data for action" (Giesecke, 1999). Surveillance data are vital for targeting public health resources. Traditionally, surveillance includes the ongoing collection, analysis, interpretation, and dissemination of data to prevent and control disease (Thacker and Berkelman, 1988). Surveillance data are useful for identifying the nature and magnitude of public health problems and evaluating the effectiveness of interventions to address those problems. In this context, the term public health surveillance is used. Public health surveillance is directed at national or regional (e.g., state or province) populations. It can be distinguished from "local" surveillance or medical screening programs. Medical screening programs are directed at a more limited population (e.g., workplace or community) and are implemented to enable early recognition of individuals needing treatment, prophylaxis, or additional education and training.

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. These data products include the following: (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.

Surveillance for pesticide poisoning identifies primarily two groups of cases, each of which requires different approaches for intervention. The first group consists of cases that are preventable by following the precautionary measures specified on product labels and in government regulation. The appropriate interventions for these cases include enhanced education and enforcement. The second group of cases occurs 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 will describe 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 comprehensive, national surveillance systems for pesticide-

*This chapter has been reviewed by the National Institute for Occupational Safety and Health, the U.S. Environmental Protection Agency, and the California Environmental Protection Agency. However, the contents of this chapter do not necessarily reflect the views of these agencies.

**Figure 27.1** Greenhouse worker dressed in protective clothing, gloves, and full-face respirator applying insecticide to potted plants. (Courtesy of Wayne T. Sanderson.)

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 will be 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 (e.g., regulations that facilitate surveillance, efforts toward standardization of 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.

## 27.2 SURVEILLANCE SYSTEMS

### 27.2.1 TOXIC EXPOSURE SURVEILLANCE SYSTEM

**Description** Most of the nation's poison control centers (PCCs) participate in a national data collection system, known as the Toxic Exposure Surveillance System (TESS). Previously, this system was called the National Data Collection System. TESS is maintained by the American Association of Poison Control Centers (AAPCC). Of the 75 PCCs in the United States, the number that participate varies from year to year. Between 1993 and 1996, the number of participating PCCs ranged from 64 to 67 (Litovitz *et al.*, 1994, 1995, 1996, 1997).

Typically, the PCCs serve a population of 1 to 10 million people, and each receives a minimum of 10,000 calls per year (Felberg *et al.*, 1996). Poison centers receive telephone calls from individuals and health care professionals seeking information on how to manage an exposure to a poison. Approximately 13% of their calls come from doctors treating exposed patients. The other 87% come from victims of the exposure or their relatives (e.g., mother of an exposed child).

Typically, a PCC is run by a hospital or university. "Poison Centers function primarily to provide poison information, telephone management and consultation, collect pertinent data, and deliver professional and public information" (AAPCC, 1988). Most of the cases (83%) in TESS are submitted by certified PCCs. To be certified, a PCC must fulfill the following criteria (AAPCC, 1988):

**1.** Have a board-certified physician on call at all times with expertise in medical toxicology.

**2.** Have poison information specialists available on site at all times to handle all calls. The poison information specialists are required to complete a training program and are certified by the AAPCC.

**3.** Maintain a comprehensive file of toxicology information sources and have ready access to a major medical library.

**4.** Maintain written operational guidelines that provide a consistent approach to evaluation and management of toxic exposures. The guidelines must include a provision for follow-up of each case to determine the patient's final disposition or medical outcome.

**5.** Have an ongoing quality assurance program, including regularly scheduled conferences, case reviews, and audits.

**6.** Keep records on all cases handled by the center with standard data elements and sufficient narrative to allow for peer review. Records must be handled using a standardized form that is acceptable as a medical record. Standard data elements include the date of the call, age and sex of the victim, location of victim at time of exposure (e.g., home, workplace), substance exposed to, route of exposure, initial symptom assessment, source of treatment (e.g., self-treated, referred to physician, hospitalized), and an evaluation of medical outcome after case follow-up (telephone contact with patient or health care professional). Beginning in 1993, information about specific symptoms experienced by the victim was also collected.

**7.** Submit all case data to the Toxic Exposure Surveillance System within deadline (2–4 times per year) and meet quality requirements. The AAPCC prepares a computer record that is returned to the local PCC (AAPCC, 1988). Taken together, all these criteria help assure the quality of the data.

**Case Definition** Cases are identified through telephone calls from individuals and health care professionals seeking information on how to manage an exposure to a pesticide. Those with symptoms are categorized into minor, moderate, or major, depending on symptom severity and whether recovery is complete. Definitions used by the poison control centers to categorize medical outcome are summarized as follows (Veltri *et al.*, 1987):

**Table 27.1**
Selected Severity Measures Used in the Analysis of the TESS Data

| Severity measure | Tables where used |
|---|---|
| $\%\text{ with symptoms} = \frac{\text{Cases reporting pesticide-related symptoms or clinical effects}}{\text{Cases with follow-up to determine medical outcome}} \times 100$ | Tables 27.3, 27.4, 27.6 |
| $\%\text{ with life-threatening or fatal outcome} = \frac{\text{Cases classified as having a major or fatal outcome}}{\text{Cases with follow-up to determine medical outcome}} \times 100$ | Table 27.4 |
| $\%\text{ seen in a health care facility} = \frac{\text{Cases seen in a health care facility}}{\text{Exposures reported to poison control centers}} \times 100$ | Table 27.5 |
| $\%\text{ hospitalized} = \frac{\text{Cases hospitalized}}{\text{Cases seen in a health care facility}} \times 100$ | Table 27.5 |
| $\%\text{ treated in a critical/intensive-care unit} = \frac{\text{Cases admitted to a critical/intensive-care unit}}{\text{Cases seen in a health care facility}} \times 100$ | Table 27.5 |

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

*Minor*. Symptoms are minimal with no residual disability (e.g., mild gastrointestinal symptoms, skin irritation, drowsiness).

*Moderate*. Symptoms are more pronounced, prolonged, or more of a systemic nature than minor symptoms with no residual disability. Usually some form of treatment is indicated. Examples include 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.

PCC poison specialists rely on their experience and judgment to determine whether cases have symptoms consistent with the toxicology, dose, and timing of the pesticide exposure. No standardized criteria are used to make this determination.

Patients treated at home or any other non–health care site are classified as "managed on site" (AAPCC, 1994). Those seen in a health care facility may be classified as either treated and released or admitted for medical care. "Admitted for medical care" is used when "the patient is observed and/or treated and subsequently admitted as an inpatient primarily to receive medical care rather than psychiatric evaluation."

For the purpose of this review, unintentional exposures to single pesticide products are emphasized because they constitute the overwhelming majority of cases and risk mitigation measures can be more easily targeted based on the known use pattern of individual pesticides. As a result, excluded from all analyses were attempted suicides, cases with intentional malicious use (e.g., attempted homicide or child abuse), cases exposing themselves for euphoric or other psychotropic effect, and cases where intent could not be determined. Together, these intentional categories account for 2.4% of all exposures. Also excluded were cases exposed to multiple products (an additional 4.1% of all exposures) and confirmed nonexposures (0.04% of all exposures).

Several measures of severity were developed for this review of PCC data (Table 27.1). The first severity measure was the percentage of cases reporting pesticide-related symptoms or clinical effects. The second measure was the percentage of cases that had a major medical outcome (as defined previously). With the first two measures, the denominator was the number of pesticide exposure cases whose medical outcome was determined (PCCs were able to determine the medical outcome for only 49% of reported exposures). A third severity measure was the percentage of *all* exposure cases that were seen in or referred to a health care facility (HCF). Among those seen in or referred to an HCF, the proportion hospitalized represents the fourth severity measure. Typically, cases are not admitted unless the attending physician feels the case is likely to require clinical observation and/or extensive treatment to prevent further adverse effects. Finally, among those seen in or referred to an HCF, the proportion admitted for critical care or treated in an intensive-care unit (ICU) represents the fifth severity measure.

**Data Source** Most of the nation's poison control centers participate in TESS. Between 1993 and 1996, the number of participating PCCs ranged from 64 to 67 (AAPCC, 1998a; Litovitz *et al.*, 1994, 1995, 1996, 1997).

**Target Population** A large proportion of the U.S. population is served by the PCCs included in TESS. Between 1993 and 1996, an average of 81% of the population was covered by participating PCCs. However, PCCs do not ascertain all cases within their catchment areas. Therefore, data from TESS are representative of the universe of exposures reported to PCCs and cannot be generalized to the entire universe of all poison exposures.

**Period of Data Collection** PCCs submit data to TESS 2–4 times per year.

**Periodicity of Reports** Data are available by calendar year. The TESS annual report, which includes information on all types of poison exposures, is published annually in the September issue of the *American Journal of Emergency Medicine*. Additional TESS data can also be purchased from the AAPCC.

Calendar year data become available 10 weeks after the conclusion of the year.

**Findings** The current review is based on 424,628 records of pesticide-related exposures reported to PCCs participating in TESS from 1993 through 1996 (Table 27.2). Pesticides accounted for 6% of all exposures reported to PCCs; in contrast, 42% of all exposures were due to pharmaceuticals. Of the 424,628 exposures, 392,209 (92%) occurred in a residential setting. The leading cause of exposures was from insecticides. Among insecticides, the organophosphates were the most common exposure (68,496 exposures).

Although attempted suicide cases made up only 2.4% of pesticide-related calls to PCCs (and are not included in the detailed review that follows), they may account for nearly 10% of the cases seen in a health care facility. The leading types of products involved in PCC cases of attempted suicide include anticoagulant rodenticides (20% of the total suicide attempts), pine oil disinfectants (14%), organophosphate insecticides (11%), pyrethrins/pyrethroids (6%), unknown rodenticides (5%), carbamate insecticides (4%), and phenol disinfectants (3%).

A primary determinant of risk to pesticides is the age of the case. Children under age 6 accounted for 91% of the rodenticide exposures, reflecting the fact that rodenticides are mostly baits used inside homes where young children have access to them. By contrast, only 28% of the herbicide exposures and 32% of the fungicide exposures involved children under age 6. These pesticides are more likely to be used and stored outside or at least where young children have less access. Half of the insecticide cases and two-thirds of the disinfectants (67%) involved exposure to a child younger than 6 years of age.

**Table 27.2**

Number of Unintentional Exposures Reported to PCCs, 1993–1996, by Pesticide Class and Age Category[a]

| Pesticide class | Child < 6 | Children 6–19 | Adults | Total[b] |
|---|---|---|---|---|
| Disinfectants | 53,617 | 6,714 | 18,889 | 79,777 |
| Fumigants | 172 | 145 | 1,794 | 2,156 |
| Fungicides | 1,445 | 494 | 2,566 | 4,569 |
| Herbicides | 7,948 | 2,850 | 17,507 | 28,728 |
| Insecticides[c] | 121,545 | 24,762 | 96,179 | 245,596 |
| Rodenticides | 57,094 | 2,095 | 3,219 | 62,733 |
| Total[d] | 242,609 | 37,127 | 140,362 | 424,628 |

[a]Excluded were suicides, cases with intentional malicious use, cases where intent could not be determined, cases exposed to multiple products, and confirmed nonexposures.

[b]Row totals include cases with undetermined age.

[c]Includes insect and moth repellents.

[d]Column totals include cases involving certain other pesticide classes (e.g., molluscicides) not listed individually.

Table 27.3 presents the information on those cases that were followed up and determined to have symptoms related to their exposure. It should be noted that only 49% of cases receive follow-up to determine final medical outcome (follow-up was determined for 51% of children under 6 years and for 46% of adults and children aged 6 years and older). Exposures that are expected to have no effect or minor effects, in the judgment of the poison specialist, often receive no follow-up and account for 38% of all exposures reported to the PCC. An additional 4% of all exposures are lost to follow-up. The remaining 9% of exposures involve individuals with health effects judged to be unrelated to their exposure.

Among cases that received follow-up to determine medical outcome, the poison specialist determined that 42% developed exposure-related symptoms. The percentage of exposures with symptoms varied across the various classes of pesticides, from only 4% for anticoagulant rodenticides up to 68% for fumigants. It should be noted that some cases avoid developing symptoms as a result of intervention measures implemented by the caretaker. The low percentage of symptomatic rodenticide exposures was likely related to the high percentage of exposures that occur among children under age 6. Parents of these children will contact a poison center even before symptoms have developed and the overwhelming majority of exposures are to anticoagulants, which have very low toxicity to humans unless ingested in high quantity or repeatedly over a short period of time. Overall, 13% of the symptomatic cases for all pesticides were moderate, major, or fatal, with percentages ranging from 6% for boric acid insecticides to 21% for fumigants (Table 27.3). Of the symptomatic cases, ingestion was the route of exposure in 51% of children under 6 years of age, 22% of children aged 6–19, and 14% of adults.

Tables 27.4 and 27.5 summarize the data on severity. Adults and children aged 6–19 were combined because their exposure patterns were similar and because the severity distribution differed little between these two groups. The three chemicals with the highest proportion for a given severity measure are indicated by a superscript of 1–3 (i.e., a 1 was assigned to the chemical with the highest proportion falling into a given severity measure). Among young children, organochlorines ranked highest in four of the five severity measures (Tables 27.4 and 27.5). This is primarily due to lindane hair shampoos intended to kill head lice. Children who accidentally ingest this product can develop life-threatening seizures. Organophosphate insecticides also ranked high (in the top 3) for young children on three of the five severity measures: percentage with life-threatening or fatal outcome, percentage hospitalized, and percentage seen in an intensive-care unit (Tables 27.4 and 27.5). Among young children, organophosphate insecticide exposures are four times more likely to result in a fatal or major outcome compared to all other pesticide exposures combined. Once in a health care facility, children exposed to organophosphates are 3 times more likely to be hospitalized and 5 times more likely to be admit-

**Table 27.3**
Number of Symptomatic Unintentional Cases and Proportion in Each Severity Category by Pesticide Class, 1993–1996[a]

| Pesticide class | Number of symptomatic cases[b] | Minor (%) | Moderate (%) | Major (%) | Fatal (%) |
|---|---|---|---|---|---|
| Disinfectants | | | | | |
| Hypochlorites | 7,663 | 84.7 | 15.1 | 0.183 | 0.000 |
| Phenols | 4,134 | 93.4 | 6.4 | 0.145 | 0.024 |
| Pine oil | 8,646 | 92.7 | 7.0 | 0.301 | 0.023 |
| Other[c] | 2,446 | 87.1 | 12.6 | 0.204 | 0.041 |
| Total | 22,889 | 89.5 | 10.2 | 0.223 | 0.017 |
| Fumigants | 823 | 78.8 | 20.2 | 0.850 | 0.122 |
| Fungicides | 1,172 | 85.9 | 13.8 | 0.256 | 0.000 |
| Herbicides | 7,573 | 86.9 | 12.7 | 0.370 | 0.026 |
| Insect repellents | 6,887 | 93.0 | 6.6 | 0.378 | 0.029 |
| Insecticides | | | | | |
| Boric acid/borates | 573 | 94.2 | 5.8 | 0.000 | 0.000 |
| Carbamates | 4,854 | 85.0 | 14.4 | 0.515 | 0.041 |
| Organochlorines | 2,503 | 84.2 | 13.8 | 1.96 | 0.080 |
| Organophosphates | 16,062 | 84.7 | 14.5 | 0.784 | 0.025 |
| Pyrethrins/pyrethroids | 13,680 | 84.3 | 15.3 | 0.417 | 0.007 |
| Other[c] | 7,069 | 86.6 | 12.8 | 0.552 | 0.028 |
| Total | 44,741 | 85.0 | 14.3 | 0.662 | 0.024 |
| Moth repellents | 1,559 | 88.3 | 11.2 | 0.449 | 0.000 |
| Rodenticides | | | | | |
| Anticoagulants | 865 | 83.4 | 15.4 | 1.27 | 0.000 |
| Other[c] | 516 | 79.4 | 18.0 | 2.33 | 0.194 |
| Total | 1,381 | 81.9 | 16.4 | 1.66 | 0.072 |
| Total[d] | 87,100 | 87.0 | 12.5 | 0.507 | 0.024 |

[a] See footnote *a* in Table 27.2.
[b] Includes cases with undetermined age.
[c] Other includes other and unknown for that category.
[d] Total includes other pesticides (e.g., molluscicides) not listed individually.

ted for critical care than children exposed to all other pesticides combined.

Among older children and adults, five groups of pesticides ranked in the top 3 for two severity measures: fumigants, carbamate insecticides, organochlorine insecticides, organophosphate insecticides, and other rodenticides (Tables 27.4 and 27.5). Adults seen for organophosphate exposure also showed a pattern of increased risk similar to children but at a much lower level. For example, the percentage hospitalized was 1.5 times that of all other pesticides combined, and the percentage seen in an intensive-care unit was 1.7 times higher. Not unexpectedly, carbamates, which have many of the same use patterns and also poison through cholinesterase inhibition, show a pattern similar to organophosphates. Those with organochlorine exposures had a high risk for life-threatening outcomes and for hospitalization. This was largely due to accidental ingestion and dermal reactions from lindane-based shampoos. Fumigants and non-anticoagulant rodenticides (these categories include methyl bromide, strychnine, phosphides, and other highly toxic compounds) had among the highest risks for fatal or life-threatening outcomes.

Table 27.6 lists the number of symptomatic cases reported by age group and site of exposure. For children under age 6, 97% of the cases occur at a residence and this figure is very consistent regardless of the class of pesticide. For adults and older children, 80% of the cases occur at a residence, 14% occur at the workplace, and 6% occur at other locations, primarily public areas such as a park or store. Symptomatic cases involving phenol disinfectants, other disinfectants, fumigants, fungicides, herbicides, and other rodenticides had the highest proportion of cases occurring at the workplace, accounting for 22%, 37%, 64%, 30%, 20%, and 23% of all exposures, respectively.

Tables 27.3–27.5 utilize proportionate hazard to rank pesticides by their potential for causing problems. Another method to examine severity is to use the incident rate, defined as the number of individuals who become ill divided by the number at risk over some time period. A surrogate measure for the population at risk can be estimated by the extent of pes-

**Table 27.4**
Among Pesticide-Exposed Individuals Who Were Successfully Followed to Determine Medical Outcome, the Number and Percentage (in Parentheses) with Pesticide-Related Symptoms and with a Major or Fatal Outcome by Age Category for Selected Pesticide Classes, 1993–1996[a]

| | Children under 6 years | | Adults and children 6–19 years | |
|---|---|---|---|---|
| Pesticide class | Number (%) with symptoms | Number (%) major or fatal outcome | Number (%) with symptoms | Number (%) major or fatal outcome |
| Disinfectants | | | | |
| Hypochlorites | 2,528 (39.9) | 4 (0.063) | 5,065 (88.1[1]) | 9 (0.156) |
| Phenols | 2,493 (42.3[1]) | 2 (0.034) | 1,612 (74.1) | 5 (0.230) |
| Pine oil | 5,306 (30.4) | 14 (0.080) | 3,296 (66.1) | 13 (0.261) |
| Other | 910 (42.1[2]) | 1 (0.046) | 1,519 (78.6) | 5 (0.259) |
| Total | 11,237 (35.3) | 21 (0.066) | 11,492 (77.4) | 32 (0.216) |
| Fumigants | 18 (19.8) | 0 (0.0) | 793 (70.6) | 8 (0.712[3]) |
| Fungicides | 117 (19.2) | 0 (0.0) | 1,035 (75.5) | 3 (0.219) |
| Herbicides | 1,033 (23.9) | 2 (0.046) | 6,453 (71.5) | 27 (0.299) |
| Insect repellents | 3,756 (41.4[3]) | 5 (0.055) | 3,087 (79.3[2]) | 23 (0.591) |
| Insecticides | | | | |
| Boric acid/borates | 267 (6.9) | 0 (0.0) | 302 (44.4) | 0 (0.0) |
| Carbamates | 1,007 (20.3) | 7 (0.141) | 3,799 (72.6) | 20 (0.382) |
| Organochlorines | 766 (27.7) | 30 (1.086[1]) | 1,714 (59.1) | 21 (0.724[2]) |
| Organophosphates | 2,871 (23.2) | 47 (0.379[2]) | 13,021 (71.0) | 82 (0.447) |
| Pyrethrins/pyrethroids | 3,031 (33.2) | 10 (0.109) | 10,515 (79.2[3]) | 48 (0.362) |
| Other | 1,788 (20.3) | 21 (0.238[3]) | 5,221 (73.5) | 20 (0.281) |
| Total | 9,730 (23.2) | 115 (0.274) | 34,572 (72.8) | 191 (0.402) |
| Moth repellents | 673 (7.2) | 6 (0.065) | 867 (51.6) | 1 (0.059) |
| Rodenticides | | | | |
| Anticoagulants | 714 (3.1) | 4 (0.018) | 145 (11.8) | 6 (0.490) |
| Other | 188 (6.0) | 5 (0.161) | 328 (48.3) | 8 (1.178[1]) |
| Total | 902 (3.5) | 9 (0.035) | 473 (24.8) | 14 (0.735) |
| Total[b] | 27,495 (22.3) | 158 (0.128) | 58,817 (72.2) | 300 (0.368) |

[a]The three chemicals with the highest proportion for a given severity measure are indicated by a superscript of 1–3 (i.e., a 1 was assigned to the chemical with the highest proportion of exposures that fell into a given severity measure). Excluded were suicides, cases with intentional malicious use, cases where intent could not be determined, cases exposed to multiple products, and confirmed nonexposures.
[b]Total includes other pesticides (e.g., molluscicides) not listed individually.

**Table 27.5**

Among All Individuals Exposed to a Particular Pesticide Class, the Number and Percentage (in Parentheses) Who Were Seen in a Health Care Facility (HCF), and of Those Seen in an HCF the Number and Percentage (in Parentheses) Who Were Hospitalized, or Treated in an Intensive-Care Unit (ICU) by Age Category, 1993–1996[a]

| | Children under 6 years | | | Adults and children 6–19 years | | |
|---|---|---|---|---|---|---|
| | | Among those seen in HCF | | | Among those seen in HCF | |
| Pesticide class | Number (%) seen in HCF | Number (%) hospitalized | Number (%) treated in ICU | Number (%) seen in HCF | Number (%) hospitalized | Number (%) treated in ICU |
| Disinfectants | | | | | | |
| Hypochlorites | 1,023 | 36 | 5 | 2,065 | 90 | 33 |
| | (10.2) | (3.52) | (0.49) | (22.4) | (4.36) | (1.60) |
| Phenols | 712 | 27 | 8 | 902 | 58 | 19 |
| | (6.5) | (3.79) | (1.12) | (21.1) | (6.43) | (2.11) |
| Pine oil | 3,974 | 240 | 71 | 1,429 | 92 | 41 |
| | (13.7) | (6.04) | (1.79) | (16.0) | (6.44) | (2.87) |
| Other | 470 | 19 | 5 | 1,086 | 44 | 12 |
| | (12.8) | (4.04) | (1.06) | (34.5[2]) | (4.05) | (1.10) |
| Total | 6,179 | 322 | 89 | 5,482 | 284 | 105 |
| | (11.5) | (5.21) | (1.44) | (21.4) | (5.18) | (1.92) |
| Fumigants | 45 | 6 | 0 | 998 | 99 | 36 |
| | (26.2) | (13.3[3]) | (0.00) | (51.5[1]) | (9.92) | (3.61) |
| Fungicides | 97 | 5 | 2 | 810 | 34 | 16 |
| | (6.7) | (5.15) | (2.06) | (26.5) | (4.20) | (1.98) |
| Herbicides | 678 | 52 | 12 | 4,772 | 329 | 132 |
| | (8.5) | (7.67) | (1.77) | (23.4) | (6.89) | (2.77) |
| Insect repellents | 1,301 | 50 | 19 | 1,167 | 40 | 16 |
| | (7.6) | (3.84) | (1.46) | (14.5) | (3.43) | (1.37) |
| Insecticides | | | | | | |
| Boric acid/borates | 775 | 29 | 5 | 222 | 9 | 5 |
| | (7.6) | (3.74) | (0.64) | (11.1) | (4.05) | (2.25) |
| Carbamates | 1,071 | 72 | 26 | 2,420 | 247 | 123 |
| | (9.6) | (6.72) | (2.43) | (19.4) | (10.2[2]) | (5.08[1]) |
| Organochlorines | 1,593 | 258 | 75 | 1,529 | 167 | 59 |
| | (39.6[1]) | (16.2[1]) | (4.71[2]) | (27.1) | (10.9[1]) | (3.86) |
| Organophosphates | 3,277 | 504 | 218 | 8,863 | 898 | 438 |
| | (13.0) | (15.4[2]) | (6.65[1]) | (21.0) | (10.1[3]) | (4.94[2]) |
| Pyrethrins/pyrethroids | 2,339 | 105 | 29 | 5,770 | 308 | 133 |
| | (13.1) | (4.49) | (1.24) | (19.7) | (5.34) | (2.30) |
| Other | 1,956 | 257 | 84 | 3,097 | 232 | 92 |
| | (10.1) | (13.1) | (4.29[3]) | (17.9) | (7.49) | (2.97) |
| Total | 11,011 | 1,225 | 437 | 21,901 | 1,861 | 850 |
| | (12.5) | (11.1) | (3.97) | (20.1) | (8.50) | (3.88) |
| Moth repellents | 3,141 | 182 | 43 | 500 | 39 | 16 |
| | (18.9) | (5.79) | (1.37) | (12.3) | (7.80) | (3.20) |
| Rodenticides | | | | | | |
| Anticoagulants | 17,177 | 354 | 51 | 1,008 | 73 | 25 |
| | (34.4[3]) | (2.06) | (0.30) | (28.7[3]) | (7.24) | (2.48) |
| Other | 2,642 | 112 | 23 | 485 | 45 | 22 |
| | (37.1[2]) | (4.24) | (0.87) | (26.9) | (9.28) | (4.54[3]) |
| Total | 19,819 | 466 | 74 | 1,493 | 118 | 47 |
| | (34.7) | (2.35) | (0.37) | (28.1) | (7.90) | (3.15) |
| Total[b] | 42,401 | 2,321 | 682 | 37,156 | 2,807 | 1,219 |
| | (17.5) | (5.47) | (1.61) | (20.9) | (7.55) | (3.28) |

[a]See footnote *a* in Table 27.4.

[b]Total includes other pesticides (e.g., molluscicides) not listed individually.

**Table 27.6**
Among Pesticide-Exposed Individuals Who Were Successfully Followed to Determine Medical Outcome, the Number of Cases (and Percentage) with Pesticide-Related Symptoms by Age Category and Site of Exposure for Selected Pesticide Classes, 1993–1996[a]

| | Children under 6 | | Adults and children 6–19 | | |
|---|---|---|---|---|---|
| Pesticide class | Residential | Other | Residential | Workplace | Other |
| Disinfectants | | | | | |
| Hypochlorites | 2,464 | 64 | 4,003 | 708 | 354 |
| | (97) | (3) | (79) | (14) | (7) |
| Phenols | 2,427 | 66 | 1,105 | 348 | 159 |
| | (97) | (3) | (68) | (22) | (10) |
| Pine oil | 5,220 | 86 | 2,955 | 179 | 162 |
| | (98) | (4) | (90) | (5) | (5) |
| Other | 847 | 63 | 720 | 562 | 237 |
| | (93) | (7) | (47) | (37) | (16) |
| Total | 10,958 | 279 | 8,783 | 1,797 | 912 |
| | (98) | (2) | (76) | (16) | (8) |
| Fumigants | 15 | 3 | 247 | 504 | 42 |
| | (83) | (17) | (31) | (64) | (5) |
| Fungicides | 111 | 6 | 672 | 307 | 56 |
| | (95) | (5) | (65) | (30) | (5) |
| Herbicides | 987 | 46 | 4,728 | 1,295 | 430 |
| | (96) | (4) | (73) | (20) | (7) |
| Insect repellents | 3,594 | 162 | 2,597 | 62 | 428 |
| | (96) | (4) | (84) | (2) | (14) |
| Insecticides | | | | | |
| Boric acid/borates | 259 | 8 | 275 | 21 | 6 |
| | (97) | (3) | (91) | (7) | (2) |
| Carbamates | 986 | 21 | 3,220 | 456 | 123 |
| | (98) | (2) | (85) | (12) | (3) |
| Organochlorines | 746 | 20 | 1,517 | 117 | 80 |
| | (97) | (3) | (88) | (7) | (5) |
| Organophosphate | 2,792 | 79 | 10,930 | 1,637 | 454 |
| | (97) | (3) | (84) | (13) | (3) |
| Pyrethrins/pyrethroids | 2,949 | 82 | 9,014 | 1,138 | 363 |
| | (97) | (3) | (86) | (11) | (3) |
| Other | 1,725 | 63 | 4,276 | 608 | 337 |
| | (96) | (4) | (82) | (12) | (6) |
| Total | 9,457 | 273 | 29,232 | 3,977 | 1,363 |
| | (97) | (3) | (84) | (12) | (4) |
| Moth repellents | 651 | 22 | 706 | 82 | 79 |
| | (97) | (3) | (81) | (9) | (9) |
| Rodenticides | | | | | |
| Anticoagulants | 683 | 31 | 120 | 13 | 12 |
| | (96) | (4) | (83) | (9) | (8) |
| Other | 181 | 7 | 233 | 76 | 19 |
| | (96) | (4) | (71) | (23) | (6) |
| Total | 864 | 38 | 353 | 89 | 31 |
| | (96) | (4) | (75) | (19) | (6) |
| Total[b] | 26,666 | 829 | 47,352 | 8,120 | 3,345 |
| | (97) | (3) | (80) | (14) | (6) |

[a] See footnote *a* in Table 27.2.
[b] Total includes other pesticides (e.g., molluscicides) not listed individually.

**Table 27.7**
Ratio of Residential Symptomatic Cases per Million Pesticide Containers in U.S. Homes by Age Category and Pesticide Class[a]

| | Children < 6 years | | | Adults and children 6+ | | |
|---|---|---|---|---|---|---|
| Pesticide class | Residential symptomatic cases[b] | Estimated containers in U.S. homes[c] (millions) | Ratio | Residential symptomatic cases[b] | Estimated containers in U.S. homes[c] (millions) | Ratio |
| Disinfectant Fungicide | 2,767 | 145.08 | 19.1 | 2,364 | 145.08 | 16.3 |
| Herbicide | 247 | 32.98 | 7.5 | 1,182 | 32.98 | 35.8 |
| Insecticide | 2,364 | 176.45 | 13.4 | 7,308 | 176.45 | 41.4 |
| Rodenticide | 216 | 4.83 | 44.7 | 88 | 4.83 | 18.3 |

[a]See footnote *a* in Table 27.2.
[b]Row totals include cases with undetermined age.
[c]Includes insect and moth repellents.
[b]The average annual number of symptomatic exposures in the residential setting for the years 1993–1996 is provided.
[c]Obtained from survey data collected in 1990 (Whitmore *et al.*, 1992).

ticide use in residential households. The U.S. Environmental Protection Agency (EPA) survey of home and garden pesticide use provided estimated numbers of containers of pesticides for all households in the United States in 1990 (Whitmore *et al.*, 1992). Table 27.7 provides the number of symptomatic cases in young children and adults/older children, the estimated number of pesticide containers in U.S. homes and provides the ratio of the number of symptomatic pesticide exposures per million containers in U.S. homes. Unfortunately, the EPA survey of home and garden pesticide use does not contain the detailed pesticide information found in TESS.

Table 27.7 shows a different pattern among young children compared to adults and older children. For children under age 6, the ratio is highest for those products typically used or stored close to the floor. The survey of households in 1990 found that about 58% of the disinfectants were stored less than 4 feet off the floor without a child-resistant closure. For fungicides, the figure was 48%; herbicides, 19%; insecticides, 32%; and rodenticides, 46%. Unlike the other pesticide classes, rodenticides are used almost exclusively as poison baits placed on the floor where children later find them. Greater use of child-resistant packaging would likely reduce the number of cases significantly, particularly for disinfectants and other products stored in bottles and not used in baits. For baits, tamper-resistant bait stations can be used to reduce exposures to children.

One measure of a pesticide's potential hazard is the frequency of cases due to exposure to residues left after application or use (as opposed to exposures directly related to application, accidental ingestion, or other direct contact). The category "environmental exposure" is used by poison control centers to capture this kind of hazard. An environmental exposure is any passive, nonoccupational exposure that results from contamination of air, water, soil, or other surfaces. Environmental exposures account for 7% of all pesticide exposures reported to PCCs (Table 27.8). Not surprisingly, fumigants and moth repellents, which are intended to contaminate the air, had the highest proportion of cases due to environmental exposures. Organophosphates were 2.5 times more likely to be involved in environmental exposures than all other pesticides combined (13% vs. 5%). In addition, a larger proportion of symptomatic cases with serious outcomes (which included moderate, major, or fatal outcomes) were due to environmental exposures compared to minor cases or asymptomatic exposures. Among symptomatic cases with a serious outcome (moderate, major, or fatal) *involving organophosphates*, nearly one-quarter of them were due to environmental exposures.

**Discussion** TESS 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. It addition, approximately half of the reported exposures receive successful follow-up. As part of this follow-up, the severity of the medical outcome is determined. The TESS also provides data for most areas of the United States.

The TESS also has some limitations. For example, PCCs do not ascertain all cases. The extent of underreporting is not known. For example, many poisoning cases seen in emergency rooms or by private physicians do not result in calls to a PCC. In a study comparing hospital data with PCC data, cases identified in a review of inpatient and outpatient medical records of all Utah acute-care hospitals were matched to records from the PCC serving Utah. It was found that only about one-third of the hospital cases were matched to PCC cases (Veltri *et al.*, 1987).

Another limitation is that not all states are included in TESS. Examination of AAPCC annual reports from 1993 through 1996 found that most or all of seven states were not served by a PCC that reported to TESS (Litovitz *et al.*, 1994, 1995, 1996, 1997). These states were Arkansas, Illinois, Maine, Mississippi, Oklahoma, South Carolina, and Vermont. Another five states (Iowa, Minnesota, Nevada, North Carolina, and Texas) had PCCs that did not report for one or two of the four years. Of

**Table 27.8**
Among All Exposure Cases, All Symptomatic Cases, and All Symptomatic Cases with a Serious Outcome, the Proportion That Were Due to Exposure to Environmental Residues of Selected Pesticide Classes, 1993–1996

| Pesticide class | Among all exposure cases, the proportion due to environmental residues (%) | Among all symptomatic cases, the proportion due to environmental residues (%) | Among all symptomatic cases with a serious outcome[b], the proportion due to residues |
|---|---|---|---|
| Disinfectants | | | |
| Hypochlorites | 5 | 7 | 9 |
| Phenols | 1 | 2 | 2 |
| Pine oil | 1 | 1 | 2 |
| Other | 2 | 2 | 4 |
| Total | 2 | 3 | 6 |
| Fumigants | 26 | 24 | 26 |
| Fungicides | 10 | 13 | 12 |
| Herbicides | 11 | 12 | 18 |
| Insect repellents | 1 | 1 | 4 |
| Insecticides | | | |
| Boric acid/borates | 2 | 6 | 6 |
| Carbamates | 9 | 13 | 18 |
| Organochlorines | 5 | 6 | 9 |
| Organophosphates | 13 | 18 | 24 |
| Pyrethrins/pyrethroids | 11 | 14 | 19 |
| Other | 13 | 19 | 27 |
| Total | 11 | 16 | 21 |
| Moth repellents | 6 | 22 | 32 |
| Rodenticides | | | |
| Anticoagulants | 0.4 | 1 | 1 |
| Other | 2 | 9 | 12 |
| Total | 1 | 4 | 6 |
| Total[c] | 7 | 11 | 17 |

[a]See footnote *a* in Table 27.2.
[b]Moderate, major, or fatal outcomes were considered serious.
[c]See footnote *b* in Table 27.6.

the 67 pesticide-related deaths from 1993 through 1996 identified in the multiple cause-of-death public use tapes (see Section 27.2.5 for more information on these data), 16 deaths (24%) occurred in one of these 12 states during a year when the state lacked coverage by the AAPCC. Thus, cases of poisoning are underestimated by TESS data.

It is also not known whether or how reported cases differ from unreported cases. In the Utah study described previously, the characteristics of unmatched cases were not studied, thereby making it impossible to determine how PCC cases differ from hospital cases that do not result in a call to a PCC (Veltri *et al.*, 1987). As a result of this selection bias, any study using PCCs as a source for cases can only be judged as 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 are not appropriate for complicated statistical analysis. However, given the large proportion of the U.S. population served by PCCs participating in TESS (81%) and the large number of poison exposures, factors identified within this selected series are likely to be helpful for targeting particular types of exposure situations for risk mitigation.

Misclassification may also occur when symptoms are reported over the phone and are not confirmed by a physician or laboratory tests. Although about 13% of calls to PCCs arise from health care professionals, the majority are calls made by the victims or their relatives. The PCC poison specialists must rely on their experience and judgment to determine which cases have symptoms consistent with the toxicology, dose, and timing of the exposure. Unlike other surveillance systems (e.g., some state-based systems participating in the Sentinel Event Notification for Occupational Risk), the AAPCC has not provided standardized criteria by which to make this determination. However, the APPCC requires that when health effects are judged to be *unrelated* to exposure, all available evidence should support this determination. 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 poison specialists are likely to misclassify one pesticide more or less than another.

It should be noted that reports in TESS are labeled "poison exposures." Many of the cases in the database never develop health effects as a result of the exposure. There are several potential explanations for the lack of health effects in these cases. These explanations include the following: Advice provided by the PCC led to prompt treatment and/or decontamination; the exposure agent was relatively nontoxic; the exposure dose was not great enough to produce toxicity; or, the exposure was suspected but actually never occurred [cases in which there is sufficient evidence that exposure never occurred are removed from TESS (Litovitz, 1998)]. Tracking symptomatic as well as asymptomatic exposure cases can be useful.

Finally, limitations involving some severity measures used in this review may be present. The severity measures may have higher or lower values because of perceptions concerning certain pesticide classes rather than the actual risks associated with them. For example, both the public and many in the health care profession are likely to perceive ingestion of rat poison as more dangerous than any other class of pesticide. 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 (e.g., just a taste) to anticoagulants, which pose relatively little risk. Similarly, decisions about which cases become hospitalized or are transferred to an intensive-care unit may be due to inaccurate perceptions of risk. Differences in the experience and style of care may affect a health care professional's choice of care. In addition, health care–seeking behavior by patients is affected by the availability and extent of health insurance coverage or workers' compensation. Often, the PCC provides advice on appropriate use of health care resources, which can result in a significant savings in health care costs.

Validity of the data collected by different poison centers is an important concern of TESS. The AAPCC conducted an audit of 588 randomly selected pesticide charts based on records submitted to the TESS in 1996 (AAPCC, 1998b). A total of 58 of these records were excluded (34 were from a center that was overrepresented in the data set, and 24 were from three centers that had closed since 1996). After these exclusions, requests for 530 cases were sent to the PCCs and 512 records were located and returned to the AAPCC for a response rate of 97%. (Thirteen records could not be located, one center did not send the three requested records, and the wrong record was sent in two cases.) Cases were reviewed to determine how accurately the information coded in TESS matched the information in the original medical record. Five fields important to this analysis were selected for the audit: reason for exposure, route of exposure, management site of case, medical outcome, and accuracy of specific and generic substance category.

Results from the audit found that the majority of cases were coded correctly (AAPCC, 1998b). Of those cases that contained errors, the most common error was insufficient follow-up to accurately code the fields. "Reason for exposure" was coded correctly 90% of the time, incorrectly coded in 4.5%, and insufficient information to determine coding in 5%. "Route of exposure" was coded correctly in 96% of cases and incorrectly coded in 3.7% [1.7% incorrect route and 2.0% route(s) omitted]. "Health care facility use and referral" was correctly coded for 93.5%, incorrect in 1.8%, and unable to determine correct coding in 4.7%. "Outcome" was correctly coded in 83%, coded incorrectly in 5%, and unable to determine correct coding in 12% (due to inadequate follow-up or missing information). "Specific" substance was correctly coded 93.3% of the time, incorrectly coded 6.5%, and unable to determine if correct 0.2%. "Generic substance" was coded correctly 98% of the time and incorrectly coded 2% of the time.

### 27.2.2 STATE-BASED SURVEILLANCE SYSTEMS

**Description** Thirty states in the United States require some form of physician, laboratory, or hospital reporting of pesticide-related illness (Freund *et al.*, 1989; Zeitz *et al.*, 1998). These states are listed in Table 27.9 along with information on the specifics of the reporting rule. Only eight states (Arizona, California, Florida, Louisiana, New York, Oregon, Texas, and Washington) routinely conduct more comprehensive case investigation and surveillance activities. In response to public concern, other states are considering initiating or expanding pesticide poisoning surveillance activities.

Until very recently, the existing surveillance systems used a variety of methods for collecting and categorizing data that did not permit the routine pooling and analysis of multi-state data. The National Institute for Occupational Safety and Health (NIOSH), with funding assistance from the EPA, has begun to address the issue of standardization of pesticide poisoning surveillance. A collaboration involving experts from federal agencies (NIOSH, EPA, National Center for Environmental Health), nonfederal agencies (Council of State and Territorial Epidemiologists, 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 is now in use by the eight states mentioned previously. These collaborating entities also developed a case definition and classification scheme that is described elsewhere in this chapter.

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 will facilitate the aggregation of these data. The aggregated data will be useful to regulatory agencies, public health policymakers, researchers, worker education programs, the public, and the medical community. This standardization will also be beneficial to other states when they initiate surveillance systems.

This section briefly describes the surveillance systems in Arizona, Florida, New York, Oregon, Texas, and Washington. These states have much in common and are not described separately in detail. The surveillance system in California that is maintained by the California Department of Pesticide Regulation (DPR) is described in a separate section, because it is the largest state-based system, has been in existence longer than the other surveillance systems, and uses a slightly different case definition. The California Department of Health Services (CDHS) recently initiated a surveillance system for occupational pesticide-related illness that is similar to the other surveillance systems described in this section. Because the CDHS system is relatively new, it will not be discussed further.

The current design of these surveillance systems involves using multiple sources for case ascertainment (these sources are listed in the following Data Source section) and active case follow-up performed either directly by the surveillance system or by partner state agencies. 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 and did not yield many cases.

Five states with pesticide-related illness and injury surveillance systems are partially funded by NIOSH through the Sentinel Event Notification System for Occupational Risk (SENSOR) program. The SENSOR program promotes state-based surveillance of selected occupational conditions, including occupational pesticide-related illness and injury. Besides tabulating the number of cases, these SENSOR-supported surveillance systems perform in-depth investigations for case confirmation, conduct screening of other workers at a case patient's workplace, and develop interventions aimed at particular industries or hazards.

**Table 27.9**
Pesticide-Related Illness Mandated Reporting Requirements and Entities by State[a]

| | | Entities mandated to report | | | | | | |
|---|---|---|---|---|---|---|---|---|
| State | Pesticide reporting requirement[b] | Physician | Hospital | Emergency room | Clinic | Laboratory | Poison control center | Other health care professional |
| Alaska | ANY OCC DZ | × | | | | | | |
| Arizona | ANY PEST | × | | | | | × | × |
| Arkansas | ANY PEST | × | × | × | × | | × | |
| California | ANY PEST | × | | | | | | |
| Connecticut | ANY OCC DZ | × | | | | | | |
| Florida | ANY PEST | × | × | | | × | | × |
| Hawaii | ANY TOXIN | × | | | | × | | |
| Iowa | ANY PEST | × | × | | | × | × | × |
| Kansas | ANY OCC DZ | × | | | | | | |
| Louisiana | ANY PEST | × | | | | | | |
| Maine | ANY OCC DZ | × | × | | | | | |
| Maryland | ANY OCC DZ | × | | | | | | |
| Massachusetts | OCC PEST | × | | | | | | |
| Michigan | ANY OCC DZ | × | × | | × | | | |
| Mississippi | ANY TOXIN | × | × | × | × | | | |
| Missouri | ANY PEST | × | × | × | × | × | | × |
| New Hampshire | ANY OCC DZ | × | | | | | | |
| New Jersey | OCC TOXIN | | × | | | | | |
| New Mexico | ANY PEST | × | | × | × | × | × | |
| New York | ANY PEST | × | × | × | × | × | | |
| Ohio | OCC PEST | × | | | | | | |
| Oregon | ANY PEST | × | × | × | × | × | × | |
| South Carolina | ANY PEST | × | × | × | × | × | | |
| Texas | OCC PEST | × | | | | × | × | |
| Utah | ANY TOXIN | × | × | | | × | | × |
| Virginia | OCC PEST | × | × | | | | | |
| Washington | ANY PEST | × | | | | | | |
| West Virginia | ANY OCC DZ | × | | | | | | |
| Wisconsin | OCC PEST | × | × | | | | | |
| Wyoming | ANY PEST | | | | | | × | |

[a]This table does not include states with only voluntary pesticide reporting requirements (Idaho, Illinois, North Dakota, South Dakota, 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 occupational 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 occupational pesticide-related illness reporting nor are there requirements for reporting poisoning from nonoccupational toxic exposures).
Sources of data: Freund *et al.* (1989), GAO (1993), Zeitz *et al.* (1998), and calls to selected states to clarify inconsistencies.

**Case Definition** These states began using the National Public Health Surveillance System case definition and classification scheme to evaluate reports starting with 1998 data. This case definition is described in detail elsewhere in this chapter (see Section 27.5).

**Data Source** All of these state-based surveillance systems require reporting of pesticide-related illness and injury cases from physicians (Table 27.9). Other sources of case reports vary by state and include poison control centers, emergency medical services, medical laboratories, hospital emergency rooms, other health care providers, clinics, migrant legal aid, selected community contacts, and state agencies with jurisdiction over pesticide use (e.g., state agricultural departments, state structural pest control boards). Some states also accept self-reports as a trigger for investigation. States also routinely review other data sources to identify additional potential cases and to evaluate the completeness of reporting. The other data sources in use include workers' compensation claims, hospital discharge data, and death certificates. Many states accept reports from sources other than those required to report through regulation.

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). 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.

**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. Although the emphasis in California and Texas has been on occupationally related cases, both the California and the Texas surveillance systems have current projects aimed at enhancing the reporting of nonoccupational cases.

**Period of Time of Data Collection** The commencement of acute pesticide-related illness and injury surveillance varies by state. Oregon has required health care providers to report pesticide poisoning since 1987, and surveillance data are considered complete beginning with the calendar year 1988. In Texas, acute occupational pesticide poisoning has been reportable since 1986, and surveillance data are considered complete beginning with the calendar year 1987. 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. In Florida, surveillance data are considered complete beginning with the 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 the calendar year 1991. Finally, Washington State has had an acute pesticide poisoning reporting requirement since 1989, and surveillance data are considered complete beginning with the calendar year 1991. In each of these states, complete data for a calendar year are generally available 12–24 months after the end of the calendar year.

**Periodicity of Reports** Printed reports are generally published annually.

**Findings** Table 27.10 provides a summary of 5 years of data from the five states with the most comparable systems and similar case classification schemes (Arizona Department of Health Services, 1992, 1993, 1994, 1995, 1996; New York State Department of Health, 1995, 1997; Pesticide Analytical and Response Center (PARC), 1991–1992, 1993, 1994, 1995, 1996; Washington State Department of Health, 1994, 1995, 1996, 1997, 1998; J. Shannon, personal communication). The data in Table 27.10 reflects the reports that have been investigated and classified as likely to be illnesses or injuries related to pesticide exposure. [The table excludes intentional poisonings (i.e., suicide and attempted suicide]).] All of these states classify between 30 and 55% of the reports received as noncases.

Insecticides are clearly the most common source of pesticide-related illness. In Arizona and Texas, herbicides, fungicides, and fumigants are responsible for a lower proportion of the total cases (in Arizona and Texas, these three pesticide classes account for approximately 12% of all pesticide-related illness cases, whereas in the other three states combined they account for 27% of all cases). These differences may be due to variations in climate and crop distribution among the states. Washington reports substantially more cases on an annual basis compared to the other four states. This may represent a true difference; however, additional factors responsible for these higher case counts may include the greater resources available in Washington to conduct both investigations and outreach activities. In addition, in Washington, like California, there is a timely referral of workers' compensation cases to the surveillance system.

Occupational exposures represent 25–97% of all cases. Texas (where only occupational pesticide poisoning cases are reportable by law) and Washington are at the upper end of this range. From 1992 to 1996, occupational cases involving agricultural exposures accounted for 13–46% of all cases in those states providing information on the location of exposure. Occupational cases caused by agricultural exposures most frequently involved pesticide mixing, loading, and application. The occupational cases that resulted from nonagricultural exposures represent a broad range of occupational classifications but were predominated by pesticide applicators, office workers, and workers in retail establishments. Often, occupational cases among office workers and retail store workers resulted from "bystander" exposures, whereby these workers did not apply the pesticide(s) but worked in proximity to where pesticides were applied or spilled.

Nonoccupational exposures that resulted in illness are most commonly related to structural and surface pesticide treatments in and around homes (i.e., bystander exposures) as well as accidental ingestions. Exposures to children (individuals less than 19 years old) represent 7–26% of all cases.

**Discussion** Among the strengths of these state systems is their reliance on a variety 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

**Table 27.10**
Number of Acute Pesticide-Related Illness Cases by Pesticide Class in Arizona, New York, Oregon, Texas, and Washington[a]

| | Arizona | | | | | New York[b] | | | | | Oregon | | | | | Texas | | | | | Washington | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pesticide class | 1992 | 1993 | 1994 | 1995 | 1996 | 1992 | 1993 | 1994 | 1995 | 1996 | 1992 | 1993 | 1994 | 1995 | 1996 | 1992 | 1993 | 1994 | 1995 | 1996 | 1992 | 1993 | 1994 | 1995 | 1996 |
| Insecticides | 24 | 25 | 26 | 37 | 18 | 62 | 25 | 38 | 39 | 42 | 30 | 30 | 41 | 31 | 26 | 16 | 16 | 44 | 38 | 80 | 94 | 178 | 116 | 98 | 128 |
| Cholinesterase-inhibiting insecticides | 14 | 14 | 18 | 9 | 10 | 23 | 16 | 20 | 20 | 23 | 18 | 15 | 32 | 16 | 19 | 2 | 5 | 24 | 22 | 35 | 58 | 112 | 70 | 44 | 67 |
| Pyrethrins/ Pyrethroids | 6 | 2 | 2 | 14 | 2 | — | — | — | — | — | 2 | 3 | 2 | 5 | 2 | 2 | 2 | 1 | 3 | 16 | 22 | 23 | 11 | 28 | 47 |
| Other insecticides | 0 | 2 | 0 | 1 | 3 | 11 | 4 | 6 | 10 | 13 | 0 | 7 | 1 | 0 | 1 | 0 | 2 | 7 | 11 | 10 | 5 | 6 | 10 | 10 | 8 |
| Combination of insecticides | 4 | 7 | 6 | 13 | 3 | 28 | 5 | 12 | 9 | 6 | 10 | 5 | 6 | 10 | 4 | 12 | 7 | 12 | 2 | 19 | 9 | 37 | 25 | 16 | 6 |
| Herbicides | 0 | 1 | 4 | 2 | 4 | 6 | 10 | 6 | 4 | 15 | 13 | 4 | 3 | 2 | 5 | 0 | 3 | 4 | 4 | 8 | 21 | 37 | 36 | 48 | 49 |
| Fungicides | 0 | 1 | 1 | 6 | 0 | 35 | 0 | 1 | 0 | 1 | 9 | 2 | 2 | 1 | 4 | 2 | 0 | 2 | 1 | 1 | 8 | 25 | 6 | 20 | 14 |
| Fumigants | 0 | 2 | 1 | 0 | 0 | — | — | — | — | — | 11 | 13 | 2 | 2 | 5 | 0 | 4 | 0 | 0 | 5 | 11 | 10 | 6 | 5 | 6 |
| Rodenticides | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 4 | 0 | 2 |
| Other | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 3 | 6 | 0 | 3 | 0 | 1 | 0 | 0 | 0 | 1 | 2 | 1 | 3 | 7 | 0 | 8 | 6 |
| Combination of pesticide class[a] | 3 | 1 | 1 | 1 | 10 | 17 | 18 | 46 | 50 | 20 | 8 | 4 | 0 | 3 | 4 | 1 | 0 | 0 | 8 | 2 | 17 | 88 | 38 | 29 | 25 |
| Unknown | 1 | 2 | 5 | 1 | 0 | 3 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 2 | 1 | 5 | 12 | 7 | 14 | 4 | 6 | 2 | 4 | 6 | 1 |
| Annual total | 28 | 33 | 38 | 48 | 32 | 124 | 56 | 93 | 96 | 84 | 72 | 56 | 48 | 42 | 45 | 24 | 35 | 58 | 67 | 106 | 160 | 347 | 210 | 214 | 231 |
| 5-year total | | | 179 | | | | | 453 | | | | | 263 | | | | | 290 | | | | | 1162 | | |
| Number of cases that were children (less than 19 years) (%) | | | 21 (12%) | | | | | 119 (26%) | | | | | 36 (14%) | | | | | 20 (7%) | | | | | 114 (10%) | | |
| Number of cases classified as occupational (%) | | | 35 (23%)[c] | | | | | 217 (48%) | | | | | 143 (54%) | | | | | 277 (96%) | | | | | 853 (73%) | | |
| Number of occupational cases that involved agricultural exposures (%) | | | Data not available | | | | | 60 (13%) | | | | | 45 (17%) | | | | | 97 (33%) | | | | | 534 (46%) | | |

[a] Intentional poisonings (i.e, suicides and attempted suicides) were excluded.
[b] Data on cases related to pyrethrins, pyrethroids, and fumigants were unavailable for New York. Such cases may be included in the categories Other insecticides and Other.
[c] For Arizona, data on occupation are available only for 1993–1996.

Washington. Other states should consider improving access to workers' compensation data as they 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. When some states have 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 fashion. 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 will occur is rather optimistic. These issues are explored in more depth later in this chapter (see Section 27.6).

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 the 198 laboratory reports of abnormally depressed cholinesterase levels received in 1995–1996, only 62 (31%) had known pesticide exposures (New York State Department of Health, 1997). The remainder of the cases 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. These data have fostered recognition of new populations at risk from exposure [e.g, workers using flea control products (Ames *et al.*, 1989)], emerging problems with pesticide products [e.g., sulfotepp (Weldon *et al.*, 1996)], and the persistence of previously identified problems [e.g., reentry interval violations resulting in illness (CDC, 1999)]. These findings are helpful for instituting needed regulatory change and for targeting education programs. Data from these state surveillance systems are marginally able to measure the magnitude of pesticide-related illness. However, the data collected adds to our understanding of the nature and extent of the problem. The standardization of data collection will allow data from these systems to be aggregated, further enhancing our understanding of acute pesticide-related illness and injury.

### 27.2.3 CALIFORNIA DEPARTMENT OF PESTICIDE REGULATION

**Description** Since 1971, the state of California has required physicians to report pesticide illnesses. During the mid-1970s, responsibility for collecting and evaluating the data moved from the Department of Public Health (later the Department of Health Services) to the Department of Food and Agriculture. Pesticide safety functions, including surveillance, were placed in the California Environmental Protection Agency's Department of Pesticide Regulation (DPR) in 1991.

Physicians are required to report by telephone to the local health officer any disease or condition that they know or have reason to believe to be caused by pesticide exposure. Within 7 days, the local health officer is required to transmit this information to the DPR. The California Pesticide Illness Surveillance Program (PISP), which is maintained by DPR supplements these physician reports with reports of occupational cases forwarded to the California Bureau of Labor Statistics (CBLS) by workers' compensation insurers. Beginning in 1987, the program has made an effort to track cases related to antimicrobial/disinfectant products. Practically all recorded antimicrobial cases are identified through the CBLS.

All identified cases (including those involving nonagricultural exposures) are referred to the agricultural commissioner in the county where the exposure occurred. The commissioner investigates the exposure circumstances and, where appropriate, takes action to enforce pesticide safety regulations. The investigation involves attempts to locate and interview the affected people and also to interview the case's supervisor and other witnesses to the event. When appropriate, investigators request the affected people to sign releases allowing them to obtain copies of relevant medical records. The state of California also supports several specialized analytic laboratories to which the commissioners can submit samples for chemical analysis, further verifying the nature and extent of exposure. DPR scientists abstract data from the commissioners' reports, including any available analytic data and medical records, and maintain it in a computerized database.

**Case Definition** Physician reporting is required for any "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 pesticide cases. Cases involving suicide and attempted suicide are also included.

The 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 incidental effects such as nausea in response to odor.

The DPR has established a standardized system for classifying the relationship between pesticide exposure and illness or injury. The classification categories are as follows:

*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 a 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.* There is some correspondence between the pesticide exposure described and the illness or injury experienced. 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 exactly where they were working when a problem began. 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 exposure suspected, 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 people 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.

Definite and probable cases generally are combined in data analyses conducted by PISP. Similarly, cases classified as unlikely, unrelated, asymptomatic, and indirect often are discussed as a group. The category of possible relationship is the most ambiguous. In practice, the possible category 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 compared to 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 either definite, probable, or possible are included in the sum.

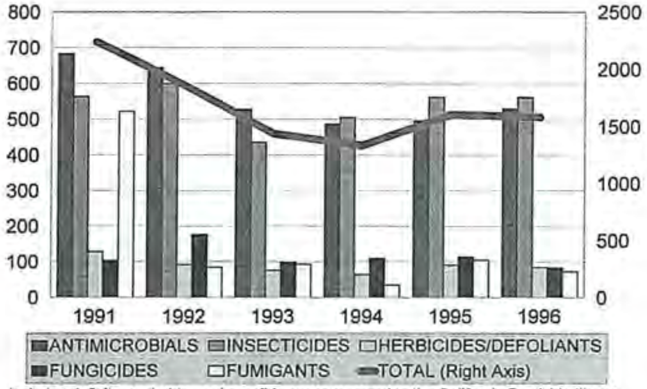
**Data Source** A total of 60–75% of the cases PISP reviews originate from workers' compensation reports reviewed at CBLS. Reporting by physicians provides the majority of the remainder. Additional cases may come to light via news media, by citizen complaints to agricultural commissioners, or by recognition in the course of an investigation.

**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 nonoccupational exposures. Complaints registered by citizens and not by physicians are investigated and forwarded to PISP at the discretion of the county agricultural commissioner.

**Period of Time of Data Collection** Annual data are made available 18–24 months after the end of the calendar year.

**Periodicity of Reports** Printed reports are published annually. The text of the report and tabulations summarizing the year's data are also available on the Internet. The Internet address for the California Department of Pesticide Regulation is http://www.cdpr.ca.gov. The PISP report can be located among the department's publications.

**Findings** Figure 27.2 provides data on the number of acute pesticide-related illnesses and injuries for the years 1991–1996. Acute pesticide-related illnesses and injuries include those cases classified as either definite, probable, or possible. The total annual number of acute pesticide-related illnesses ranged from 1332 to 2239 during this period, and an overall downward trend is evident. From 1991 to 1993, antimicrobials/disinfectants were responsible for the largest proportion of cases. Between 1994 and 1996, insecticides became the dominant source of cases. Among insecticides, organophosphates and insecticide combinations were most commonly responsible (Fig. 27.3). A train derailment that caused a metam-sodium spill accounted for the high number of cases involving fumigants in 1991. In that incident, approximately 19,000 gallons of metam-sodium spilled into a river, liberating methylisothiocyanate




Includes definite, probable, and possible cases reported to the California Pesticide Illness Surveillance Program

**Figure 27.2** Number of acute pesticide-related illnesses by pesticide category in California, 1991–1996.

vapor. That incident was associated with illness in 435 individuals. The high number of cases involving insecticide combinations in 1996 was largely due to a single large drift episode that involved exposure to an organophosphate/pyrethroid combination. In that episode, 230 farmworkers became ill when the insecticide combination that was aerially sprayed on a neighboring field drifted onto the field where the farmworkers labored. Between 1991 and 1996, 34% of all pesticide-related illnesses were associated with agricultural exposures.

Since the mid-1970s, county agricultural commissioners have usually investigated 2000–3000 cases each year. Among all cases that were investigated between 1991 and 1996, 18% were classified as definite, 25% were classified as probable, and 23% were classified as possible. The remaining 34% of cases were classified as unlikely, unrelated, asymptomatic, or indirect.

From 1991 to 1996, an average of 9.4% of pesticide-related illness was associated with exposure to lingering field pesticide residues [in contrast to illnesses associated with the pesticide application process (including exposures from drift), accidental ingestion, or other direct contact (e.g., exposure to residue from structural applications)]. After 1988, when California imposed

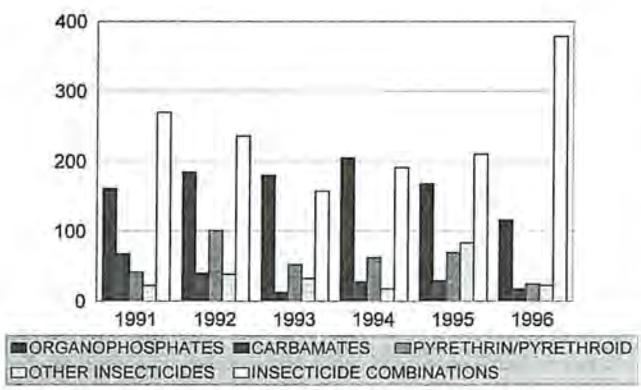



**Figure 27.3** Number of acute insecticide-related illnesses by insecticide category in California, 1991–1996.

regulations to lengthen restricted entry intervals for several pesticides, the average annual number of illnesses attributed to field residue exposures dropped 44% (from an annual average of 282 illness cases between 1982 and 1988, to an average of 158 cases between 1989 and 1996). The decrease occurred primarily among complaints of skin irritation (from an annual average of 221 illness cases between 1982 and 1988 to an average of 103 cases between 1989 and 1996). The number of systemic illnesses associated with field residue exposures has changed little between 1982 and 1996, averaging 58 cases per year.

**Discussion** The California PISP provides the most comprehensive source of verified information on adverse health effects of pesticides in the United States. Alone among state surveillance systems, 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 a trained professional. The PISP only rarely includes individuals who did not seek medical attention.

The large numbers of cases identified through workers' compensation reports, and not by direct physician reporting, demonstrates that physician reporting is incomplete. This suggests that nonoccupational cases may not be fully reported. The surveillance program has been instrumental, however, in identifying opportunities for mitigation through the regulatory program.

### 27.2.4 BUREAU OF LABOR STATISTICS (BLS)

**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. Beginning in 1992, the information provided in these reports was enhanced to provide additional information on occupational injuries and illnesses. Among the enhancements was the commencement of reporting occupational pesticide-related illnesses and injuries. However, estimates of total numbers of specific occupational injuries and illnesses are not provided. Instead, data are available only when the condition resulted in the worker being away from work for one or more days.

The illness and injury estimates provided in these reports are obtained through an annual survey of employers (Bureau of Labor Statistics (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

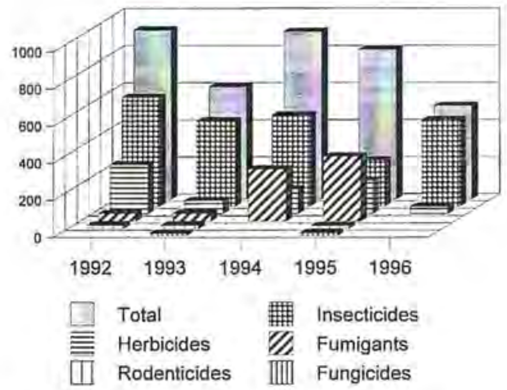



**Figure 27.4** Number of pesticide-related illness cases by pesticide class/BLS data.

state. Employers are stratified by their standard industrial classification (SIC) code and by employment size. Employers are then sampled from these strata. For the classes that contain the largest employers, the allocation procedure places all of the establishments of the frame in the sample; as employment size decreases, smaller and smaller proportions of establishments are included in the sample. The response rate is generally over 90% for sampled establishments. By a weighting procedure, sample units are made to represent all units within a sampling strata.

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

**Data Source** An annual survey of employers (see the preceding Description section).

**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, which account for approximately 50% of farms (NASS, 1998); 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.

**Period of Time of Data Collection** Approximately 16 months are required to collect, compile, and publish findings following a given calendar year.

**Periodicity of Reports** Printed reports are published annually. Data are also available on the Internet at http://stats.bls.gov/oshhome.htm.

**Findings** Between 1992 and 1996, the annual number of pesticide-related illness and injury cases ranged from 504 to 914 (Fig. 27.4). In each of these years, insecticides were responsible for most cases (with 1995 being the exception when fumigants were responsible for most cases).

**Discussion** The 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 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.

### 27.2.5 VITAL STATUS STATISTICS: MULTIPLE CAUSES OF DEATH

**Description** The National Center for Health Statistics (NCHS) of the Centers for Disease Control and Prevention (CDC) releases a public-use vital statistics tape file for each data year. This file contains a data record of 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 tapes can be purchased from the National Technical Information Service or from the Government Printing Office. Additional information on obtaining these tapes can be obtained on the Internet at http://www.cdc.gov/nchswww/.

**Case Definition** Any of the following causes of death mentioned on the death certificate (*International Classification of Diseases*, 9th revision): E863.0, E863.1, E863.2, E863.3, E863.4, E863.5, E863.6, E863.7, E863.8 and E863.9 (the pesticide class that corresponds to each of these codes is provided in Table 27.11). Separate codes are used for suicidal poisonings and poisonings possibly related to suicide. Suicides and possible suicides were excluded from the following analysis. In addition, data on specific pesticide products are not available.

**Data Source** Multiple-cause-of-death public-use tape files have been released for each data year beginning in 1968. Only incomplete data are available for 1972, 1981, and 1982.

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

**Period of Time of Data Collection** Approximately 18 months are required to collect, compile, and publish findings for a given calendar year.

**Periodicity of Reports** Public-use data tapes are available annually.

**Table 27.11**
Counts of Pesticide-Related Deaths by Pesticide Class Using Multiple-Cause-of-Death Data, 1987–1996[a,b]

| Pesticide-related cause of death ("E" code) | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Insecticides of organochlorine compounds (E863.0) | 2 | 0 | 0 | 0 | 4 | 4 | 0 | 1 | 0 | 0 | 11 |
| Insecticides of organophosphorus compounds (E863.1) | 5 | 2 | 3 | 5 | 4 | 4 | 4 | 4 | 4 | 5 | 40 |
| Carbamates (E863.2) | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 4 |
| Mixtures of insecticides (E863.3) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Other and unspecified insecticides (E863.4) | 3 | 3 | 4 | 1 | 1 | 5 | 7 | 0 | 1 | 4 | 29 |
| Herbicides (E863.5) | 4 | 5 | 6 | 1 | 1 | 1 | 2 | 2 | 1 | 2 | 25 |
| Fungicides (E863.6) | 0 | 2 | 0 | 0 | 1 | 1 | 2 | 1 | 1 | 0 | 8 |
| Rodenticides (E863.7) | 2 | 2 | 5 | 4 | 1 | 1 | 3 | 1 | 0 | 0 | 19 |
| Fumigants (E863.8) | 1 | 0 | 3 | 1 | 0 | 0 | 1 | 1 | 1 | 4 | 12 |
| Other and Unspecified (E863.9) | 4 | 4 | 7 | 2 | 0 | 4 | 3 | 4 | 3 | 4 | 35 |
| Total | 21 | 19 | 28 | 15 | 13 | 20 | 22 | 15 | 11 | 19 | 183 |

[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).
[b]Suicides and possible suicides were excluded.

**Findings** Between 1987 and 1996, there were a total of 183 deaths related to pesticides. During this 10-year period, the annual number of death certificates that mentioned pesticide-related illness and injury ranged from 11 to 28 (Table 27.11). Organophosphate insecticides were mentioned on 40 death certificates, making this the most common pesticide class associated with pesticide-related deaths (Table 27.11).

Although most of the pesticide-related deaths were among adults, 19 (10%) were among children under the age of 10 (17 of whom were under the age of 6). Most of the pesticide fatalities were among whites (71%) and males (73%). However, blacks accounted for a disproportionate number of cases (26%).

There are only limited data available on the circumstances of these pesticide-related deaths. A total of 67 (37%) occurred in the home, 5 (3%) occurred in a public building, 3 (2%) occurred in industry, 9 (5%) were noted to have occurred in an "other" location, and one (1%) occurred on a farm. Data on the location of the poisoning were not available for 98 (54%) of the deaths.

**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 over the past 10 years. 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 under 10-years of age. Between 1987 and 1996, these children accounted for 10% of the pesticide-related deaths. This is low when considering that children under the age of 10 comprised 15% of the U.S. population (U.S. Bureau of the Census, 1995). (It should be noted that children under the age of 6 accounted for 9% of all pesticide-related deaths and also comprised 9% of the U.S. population.) Furthermore, children less than 10 years of age accounted for a lower proportion of all pesticide-related deaths during this 10-year period compared to the more distant past. In 1974, the proportion was 32%, whereas, in the more distant past, it was over 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.

As has been documented in the past, blacks account for a disproportionately high number of cases. In 1990, 12% of the U.S. population was black (U.S. Bureau of the Census, 1995), which contrasts with the fact that blacks accounted for 26% of the pesticide-related deaths between 1987 and 1996.

The limitations of this data source are many. First, only the most severe 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 1973–1974 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, marital status, and place of the accident.

### 27.2.6 NATIONAL HOSPITAL DISCHARGE STUDIES: COLORADO STATE UNIVERSITY

**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.

**Case Definition** Hospitalized pesticide poisoning case.

**Data Source** A survey of general-care hospitals (see the preceding Description section). 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.

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

**Period of Time of Data Collection** The last survey covered the time period 1977–1982.

**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).

**Findings** Between 1977 and 1982 in the United States, the average annual number of hospitalized unintentional pesticide poisoning cases was estimated at 2380 (range: 2127–2991). 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-dichlorophenoxyacetic acid (2,4-D), mevinphos, methyl parathion, disulfoton, aldicarb, and glyphosate (Blondell, 1997). Children 0–4 years of age accounted for 57% of all unintentional nonoccupational hospitalized pesticide poisoning cases.

**Discussion** These hospital discharge data are a useful source of data on severe pesticide poisoning cases. Unfortunately, the most recently available data are from the period 1977–1982. Funding for this study was cut by the EPA in the early 1980s due to agency budget cuts and redirected priorities. It is interesting that the number of hospitalized pesticide poisoning cases estimated using these data are similar to the average annual number of such cases identified by TESS (see Table 27.5). As there are data to suggest that TESS underestimates the number of pesticide poisonings cases seen in hospitals (Veltri *et al.*, 1987), these data from Colorado State University may similarly provide underestimates of the true incidence. Furthermore, because the data are obtained from a weighted sample and not from a census of all hospitals, one is led to suspect that some imprecision exists in the estimates.

### 27.2.7 NATIONAL HOSPITAL DISCHARGE SURVEY: NATIONAL CENTER FOR HEALTH STATISTICS

**Description** The National Center for Health Statistics (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, persons 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 Veterans Administration hospitals are excluded, as are hospital units of institutions (e.g., prison hospitals), and hospitals with less than six beds.

The poisoning estimates provided by the study are based on a stratified three-stage design. For 1996, data were collected for 282,000 patient discharges from the 480 responding hospitals. Items available in this data set include age, sex, race, ethnicity, marital status, geographic region of the hospital, discharge diagnoses (up to 7) coded into *International Classification of Diseases*, 9th revision (ICD-9) (World Health Organization, 1977) categories, and expected source of payment. Occupation of the patient is not available.

**Case Definition** Hospitalized accidental pesticide poisoning case. Any of the following diagnoses were eligible for inclusion (*International Classification of Diseases*, 9th revision): E863.0, E863.1, E863.2, E863.3, E863.4, E863.5, E863.6, E863.7, E863.8, and E863.9 (the pesticide class that corresponds to each of these codes is provided in Table 27.11). Separate codes are used for suicidal poisonings and poisonings possibly related to suicide. Suicides and possible suicides were excluded from the following analysis.

**Data Source** A survey of general-care hospitals (see the preceding Description section).

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

**Period of Time of Data Collection** Annual surveys have been conducted since 1965.

**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.

**Findings** In 1996, there were an estimated 936 discharges with an E863 discharge diagnosis (accidental poisoning by agricultural and horticultural chemical and pharmaceutical preparations other than plant foods and fertilizers). Of these, 339 involved organochlorines (E863.0), 95 involved organophosphates (E863.1), 129 involved other insecticides (E863.4), and 373 involved rodenticides (E863.7) NCHS, (unpublished data).

**Discussion** The National Hospital Discharge Survey is not a reliable source of data for acute pesticide-related illness and injury. Only 50–60% of the sampled hospitals provide data on E codes. For this reason, E-code data are not published in the annual reports of the National Hospital Discharge Survey. The findings we provide are not consistent with other sources of pesticide poisoning data. For example, organochlorines accounted for 36% of hospital discharges involving pesticide poisonings. In contrast, the National Hospital Discharge Study conducted by Colorado State University for 1977–1982 found that chlorinated hydrocarbon pesticides accounted for 9% of hospitalized occupational pesticide poisonings. In addition, the TESS data for 1993–1996 found that organochlorine insecticides accounted for 8% of hospitalized pesticide poisonings (see Table 27.5). These findings, together with the trend in declining use of the organochlorines, provide additional support for the unreliability of the National Hospital Discharge Survey data for surveillance of acute pesticide-related illness and injury.

### 27.2.8 SOUTH CAROLINA HOSPITAL DISCHARGE SURVEYS

**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 the period 1971–1973 (Caldwell and Watson, 1975). In the most recent survey (which included the years 1992–1996), all primary-care hospitals in South Carolina were invited to participate. Sixty-two hospitals (90%) participated.

**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). Intentional poisonings (e.g., suicides and suicide attempts) were included.

**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 (see the preceding Description section).

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

**Period of Time of Data Collection** Periodic surveys have been conducted since the early 1970s.

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

**Findings** The most recent survey found that there were 112 hospitalized pesticide-related cases during the years 1992–1996 (with a mean of 22 cases/year) (Caldwell *et al.*, 1997). Intentional ingestions accounted for 40% of the cases. Unintentional nonoccupational poisonings accounted for 57% of the cases (this category included 26 adults and 31 children). Only 9 (8%) cases had an occupational etiology, 8 of which occurred in an agricultural setting.

**Discussion** Using hospital inpatient data, a decline in pesticide-related illness and injury has been observed in South Carolina. The average annual number of cases has declined from a peak of 79 cases/year during 1979–1982 to 22 cases/year during 1992–1996. The decline in occupationally related cases is thought to have played the largest role in this decline (from a mean of 20 cases/year during 1979–1982 to a mean 2 cases/year during 1992–1996). The authors of the most recent survey attribute this 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).

Because this survey includes data only on hospitalized cases, only the most severe pesticide-related illnesses are captured.

The most recent survey included information on outpatient emergency room visits from the 56% of participating hospitals that had this information in computerized format. As more hospitals move to electronic data storage, the outpatient data will become an important source of surveillance information.

### 27.2.9 NATIONAL AGRICULTURAL WORKERS SURVEY

**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 Department of Agriculture to the Department of Labor in 1987, and the National Agricultural Workers Survey (NAWS) reached its present form in 1989. The survey interviews about 1500 agricultural workers in each of three annual interview cycles. Cycles begin in February, June, and October and last 15–16 weeks.

Interviewees 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 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 outside of working hours and are offered a $10.00 honorarium for responding to a personal interview that lasts about an hour.

The 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 EPA has contributed a limited set of questions designed to elicit information about health effects associated with pesticide exposure. Beginning with the October 1998 cycle, the health effects questions were expanded and improved. The survey now includes questions on medical history, use of medical services, participation in pesticide training, and housing conditions. A complete occupational history for the year preceding the interview is also obtained. 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.

Periodic reports presenting aggregate findings are available from the Office of the Assistant Secretary for Policy of the U.S. Department of Labor. A public-use tape containing data on approximately 13,000 farmworkers collected between 1993 and 1998 is available. Finally, if the desired data are not available in published reports or in the public-use tape, specialized analyses can be requested from NAWS staff. Additional information on NAWS is available on the Internet at http://www.dol.gov/dol/asp/public/programs/agworker/naws.htm.

### 27.2.10 INTERNATIONAL SURVEILLANCE EFFORTS

Estimates of the worldwide toll of pesticide toxicity are based on mathematical models. The summary by Levine and Doull (1992) provides an overview of the approaches taken and the available observational inputs. The observational inputs generally consist of mortality records and estimates of the proportion of pesticide-related illnesses that are fatal. Other worldwide estimates use hospitalization data along with mortality data. Finally, some estimates are based on projections of the number of workers exposed to pesticides and the proportion of these workers who experience symptoms of pesticide-related illness. The World Health Organization (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).

Many surveys and case series concerning the health effects of pesticides are published in local or regional journals not readily accessible in other parts of the world. Others summarize the experience of referral or resource centers. Examples of this approach include a review of pesticide fatalities in Spain (Garcia-Repetto *et al.*, 1998) and a review of calls to the Greek Poison Center (Vlachos *et al.*, 1982).

The following discussion summarizes primarily reports in internationally available publications that describe systematic, ongoing efforts to record health effects attributable to pesticide exposure. Some surveys are referenced where they provide insight into conditions in areas not covered by ongoing surveillance systems.

Among European nations, the United Kingdom (UK), Romania, and Russia attempt formal ongoing surveillance. Additionally, a review of hospital records for Finland (Lamminpää and Riihimäki, 1992) found pesticides to be a rare cause of hospitalization. Persson *et al.* (1997) collected reports from the Swedish Poisons Information Center, as well as reviewing hospital and death records. They concluded similarly that "the incidence of acute pesticide poisonings in Sweden is low" (Tables 27.12 and 27.13).

The UK surveillance system for pesticide poisoning is implemented primarily through a Pesticide Incidents Appraisal Panel (Health and Safety Executive, 1997). Episodes of pesticide exposure are reported to the panel by the Health and Safety Executive and by local authorities (Table 27.12). The panel includes medical doctors, toxicologists, and poison information specialists. It classifies cases on a consensus basis as confirmed, likely, or unrelated. Because not all investigations obtain the information needed to assign cases to these categories, some cases receive open assessments or are left pending or designated as providing insufficient information. Since 1994,

**Table 27.12**
Annual Fatalities Ascribed to Pesticide Intoxication by Country

| Country (source of data) | Time period | Average annual number of deaths (SD) | Percent self-inflicted | Approximate population (millions) | Annual rate of all pesticide fatalities/ million | 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 |
| Romania (Fabritius and Balasescu, 1996)[c] | 1988–1993 | 82 (24.5) | 56 | <10 | >8 | >3.5 |
| Sri Lanka (de Alwis and Salgado, 1988)[d] | 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 27.2.5)[e] | 1987–1996 | 18 | 0 | 249 | — | 0.07 |

SD, standard deviation; —, data not available.
[a]Excludes self-inflicted poisoning deaths.
[b]Data presented are crude figures derived from official sources and thought more likely to be comparable to the other entries in this table. A chart review conducted by Wesseling *et al.* identified additional cases (revised annual number of deaths/year, 61.3) and called into question the percentage of deaths that were self-inflicted (revised estimate, 62%).
[c]Data are presented for 28 counties, nonoccupational intoxications only. The covered area comprises less than half the population of Romania, but has higher rates of toxicity than the rest of the country.
[d]Percentage self-inflicted based on review of a sample.
[e]These data contain only unintentional cases.

**Table 27.13**
Annual Hospitalizations Ascribed to Pesticide Intoxication

| Country (source of data) | Time period | Average annual number of admissions (SD) | Percent self-inflicted | Approximate population (millions) | Annual rate of all pesticide poisoning hospital-izations/ million | Annual rate of unintentional pesticide poisoning hospital-izations/ million[a] |
|---|---|---|---|---|---|---|
| Costa Rica (Wesseling *et al.*, 1993) | 1980–1986 | 476 | 24 | 2 | 238 | 181 |
| Sri Lanka (de Alwis and Salgado, 1988) | 1975–1983 | 13,688 (1,921) | 75 | 14.5 | 944 | 236 |
| Finland (Lamminpää and Riihimäki, 1992) | 1980, 1981, 1982, 1987, 1988 | 78 | 31 | 4.7 | 16.6 | 11.5 |
| Sweden (Persson *et al.*, 1997) | 1978–1983 1988–1993 | 50–60 | — | 8 | 7 | — |
| United States (Keefe *et al.*, 1990) | 1977–1982 | 2,834 | 16 | 227 | 11.4 | 9.6 |

SD, standard deviation; —, data not available.
[a]Excludes hospitalizations due to self-inflicted poisoning.

the panel has also assessed the character of health effects, classifying them as acute or chronic; local or systemic; and mild, moderate (requiring medical intervention), or severe (requiring inpatient therapy). In most years, this system records fewer than 100 cases and classifies fewer than half of them as confirmed or likely. Several sources have voiced concern that reporting may be seriously incomplete and recommended efforts to improve notification of the panel about pesticide poisoning cases.

The purpose of the UK surveillance system is to identify "unanticipated adverse effects of new pesticides or previously unrecognized effects of established products" and to help "inform decisions about appropriate control measures, research needs and resource allocation." A recent review of the surveillance system concluded that the data collected from accident and emergency departments, data from inpatient stays, and death data could provide an indication of the overall magnitude of the problem, but did not supply enough specific information to fulfill the purpose of identifying the effects of particular pesticides (G. Jones, Health and Safety Executive, personal communication). Records of the National Poisons Information Service sometimes include information to assess the effects of particular pesticides. However, only those cases investigated by the Pesticide Incidents Appraisal Panel regularly recorded the critical features of pesticide-related illness and injury episodes.

Fabritius and Balasescu (1996) describe the situation in Romania. There, sanitary police and preventive health care units file reporting cards for pesticide intoxications, among other conditions. A review of these reports for 26 counties identified hundreds of deaths annually. In Romania as in the United Kingdom, unexplained variations in the data suggested incomplete reporting.

In Russia, the Federal Ministry of Public Health's Center on Sanitary Epidemiological Surveillance cooperated with the Computer Center of the Russian Academy of Sciences to develop an enhanced version of a database on pesticides (Cilovtsev *et al.*, 1998). The updated software, known as PESTOTEST, supports decision making at federal, regional, and local levels.

Estimates of pesticide morbidity and mortality in eastern Asia are sparse. They rely heavily on a review of hospital records for the year 1979 in Sri Lanka (Jeyaratnam *et al.*, 1982) and an interview survey of agricultural workers in Indonesia, Malaysia, Sri Lanka, and Thailand (Jeyaratnam *et al.*, 1987). In addition, Sri Lanka's judicial medical officer and his deputy reviewed deaths and hospital admissions for the years 1975 through 1983 (de Alwis and Salgado, 1988). During that period, pesticide poisoning accounted for 4% of all autopsy cases (over 1000 deaths per year) and for more than 10,000 hospital admissions each year (Tables 27.12 and 27.13).

Chan *et al.* (1996) mention surveillance for vegetable-borne pesticide poisoning in Hong Kong in the context of a review of inquiries to the Drug and Poisons Information Bureau and of medical records at a major Hong Kong hospital. Hong Kong has been subject to repeated outbreaks of methamidophos poisoning from contaminated vegetables. In 1992 alone, 47 outbreaks of methamidophos toxicity were recorded, presumably affecting hundreds of individuals. Otherwise, few poisoning episodes were identified in Hong Kong.

In Africa, surveillance data are available for only two countries (South Africa and Kenya). In South Africa, the Health Act makes pesticide poisoning a notifiable condition. The Department of National Health and Population Development receives any notifications. London *et al.* (1994) analyzed the reports of pesticide poisoning collected from 1987 to 1991 by one regional office. They also reviewed hospital records for the same period and found that the majority of hospitalizations had not been reported.

A small-scale attempt to monitor the health of pesticide users and formulators began in Kenya during 1997 (Kimani and MacDermott, 1998). Amos (1998) reported that a survey of cocoa farmers in Nigeria found some physical complaints to be strongly correlated with pesticide use.

In Central America, the surveillance system in Nicaragua serves as a model for other countries in this region. Nicaragua included pesticide poisoning among notifiable conditions in 1979, when the National Unified Health System was established (Cole *et al.*, 1988). Initially, few cases were reported. By 1987, the system was capable of identifying an epidemic of pesticide poisoning that resulted from increased pesticide usage, which was encouraged by loan subsidies and a favorable exchange rate coupled with deregulation of the price of crops (McConnell and Hruska, 1993). An evaluation by Keifer *et al.* (1996) still detected substantial underreporting, however.

Reviews of medical records in Costa Rica (Leveridge, 1998; Wesseling *et al.*, 1993) demonstrated that pesticide poisoning was a substantial public health problem (Tables 27.12 and 27.13). Costa Rica declared mandatory reporting of pesticide intoxication in 1983 and subsequently undertook a pilot surveillance project, with support from the Swedish Agency for International Development, that focused on a single county. The Pan American Health Organization and WHO later joined this effort. Surveillance has since extended to the Atlantic region, with additional areas scheduled for inclusion (Castro *et al.*, 1998). The Costa Rican system is organized hierarchically

**Figure 27.5** Team of workers using backpack sprayers to apply herbicide to sugarcane field in South Africa. (Courtesy of Wayne T. Sanderson.)

(Antich, 1998). Each health center transmits case records to its immediate hierarchical superior. These collection points forward their data to their superiors, until all reports arrive at the national office. Software identifies possible duplicate entries and flags cases for investigation based on criteria of severity (such as fatality) or social importance (such as pediatric poisoning).

In 1997, again with support from the Pan American Health Organization and WHO, Mexico established surveillance for pesticide illness in the states of Sonora and Sinaloa (Alvarez *et al.*, 1998). This effort used a broad case definition, intending to record "all persons of any age or sex suspected to have acute or chronic adverse health effects related to pesticide exposure." After a period of outreach to physicians, nurses, agricultural specialists, and the community, the system collected case reports passively from health centers, clinics, and hospitals and performed active surveillance in some high-risk situations. Staff also reviewed existing mortality data and medical or hospital registries to identify cases. From March through December of 1997, Sonora reported 42 cases and Sinaloa reported 44 cases of pesticide-related illness.

In South America, pesticide-related illness and injury surveillance is conducted in Brazil and Uruguay. In 1982, surveillance efforts began in the Campinas region of the Brazilian state of São Paulo (Trape and Zambrone, 1991). A report on improvement efforts (de Oliveira, 1998) implied continued existence of a Brazilian program. Absence of reports from one region led to design of a sentinel event system, with preparation of instruments for follow-up of index cases reported by specially trained health professionals.

A single toxicology information center has served all of Uruguay since 1975 (Burger, 1998). The records kept there indicate that during the earliest years pesticides were responsible for one-quarter of the center's consultations. Pesticides still contributed 15% of the case load in 1997.

## 27.3 U.S. ENVIRONMENTAL PROTECTION AGENCY REGULATIONS

The 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 the acute adverse effects of pesticides and the regulatory programs available to implement risk mitigation.

### 27.3.1 THE FEDERAL INSECTICIDE, FUNGICIDE, AND RODENTICIDE ACT

The EPA regulates the use of pesticides in the United States under the authority of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). No pesticide may legally be sold or used in the United States unless it bears an 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 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.

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, the 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 that require the certified applicator to demonstrate competency with respect to the use and handling of pesticides. States also have the responsibility for enforcement of FIFRA (e.g., investigating and issuing penalties for a label violation).

The pesticide label provides directions on how, when, and where a pesticide can legally be used and which pests can be controlled. The 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, and 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 (Toxicity Categories II, III, and 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 describe the protective clothing and other equipment that must be used. 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 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. Label statements may limit the amount used by specifying the frequency of application, amounts handled, acreage treated, or the rate of application. Application may require enclosed 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 or not wearing contaminated clothing the next day. After application, a restricted-entry interval may be imposed when unprotected persons are not permitted in the treated area. Posting and/or notification may be required to warn bystanders and others not directly involved in the application.

Formulation and packaging requirements can also be imposed under FIFRA to reduce the risk from pesticides. For example, the container size or percentage active ingredient may be limited. Formulation 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, 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.

### 27.3.2 FEDERAL REPORTING REQUIREMENTS FOR RISK INFORMATION

Section 6(a)(2) of FIFRA requires pesticide registrants to submit to EPA information concerning adverse effects of their products. The purpose of this requirement is to help ensure that EPA decisions to register a pesticide as well as 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 toxicological and ecological studies, antimicrobial product efficacy failure data, and incident reports. Incident reports may involve humans, domestic animals, wildlife, plants, surface or groundwater contamination, or property damage. When the 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, the regulations specify detailed information to be provided with serious or rare incidents. Common or minor incidents, on the other hand, can be summarized as counts by product or active ingredient. For example, for the 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 how exposed, use site, situation (e.g., household application, field reentry), and evidence that the label directions were not followed. Adverse-effect 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 hospital inpatient), time between exposure and onset of symptoms, and estimated duration or amount of exposure, if available. Some registrants have elected to use the services of poison control centers to handle inquiries about adverse-effect incidents concerning their products.

### 27.3.3 NATIONAL PESTICIDE TELECOMMUNICATIONS NETWORK

The National Pesticide Telecommunications Network (NPTN) is a toll-free telephone service that provides pesticide information to any caller in the United States, Puerto Rico, or the Virgin Islands. The service is funded by the 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 800 pesticide active ingredients incorporated into over 20,000 different products registered for use in the United States. The NPTN operates 7 days a week, excluding holidays, from 6:30 AM to 4:30 PM Pacific time. The NPTN can be reached by telephone at 1-800-858-7378, by fax at 1-541-737-0761, or on the Internet at http://ace.orst.edu/info/nptn/.

Also at the NPTN is the National Antimicrobial Information Network (NAIN), which provides similar information about antimicrobial products—sanitizers, disinfectants, and sterilants—by phone or mail. The NAIN has the same operating schedule as the NPTN. Its telephone number is 1-800-447-6349; the fax number is 1-541-737-0761. The Web site address is http://ace.orst.edu/info/nain/.

### 27.3.4 WORKER PROTECTION STANDARD

In 1992, EPA revised the worker protection standard concerning protection of agricultural workers from pesticide exposure. The purpose of the revised standard is to reduce pesticide exposure among agricultural workers and thereby reduce the risk of pesticide poisonings and potential chronic effects. Under this standard, workers employed at farms, forests, nurseries, and greenhouses receive notification about pesticide applications so they may avoid treated areas. All workers must receive safety training about pesticides and appropriate protective measures. For hazardous pesticides, decontamination soap and water must be available on site. Emergency assistance in the form of transport to an appropriate medical facility must be provided in the case of a suspected pesticide poisoning, and the employer must provide information about the pesticide to which the person may have been exposed. Depending on the toxicity of the pesticide, additional requirements for personal protective equipment and restricted-entry intervals may also be required. Workers are excluded from entering a pesticide-treated area during the restricted-entry interval, with only narrow exceptions.

## 27.4 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, 1988) and are briefly summarized here.

When evaluating surveillance systems, it is important to describe the public health importance of the health event of interest. The information provided earlier 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). Finally, acute pesticide-related illness and injury is preventable through appropriate training and by taking appropriate safeguards.

It is also important to assess the usefulness of the surveillance system. This can include describing the actions taken as a result of using data from the surveillance system (e.g., policy changes, regulatory changes, clinical practice changes, etc.) 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 is identified by the system? 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, and outcomes/diseases/exposures.

*Simplicity.* The system should be as simple as possible. There are several measures to be considered. Is the case definition easy to apply? Are there multiple levels of reporting? 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?

*Acceptability.* This attribute assesses the willingness of individuals and organizations to participate in the system. Several factors influence acceptability. What is the public health importance of the health event of interest? Is there timely recognition of an individual's contribution? Are the time and personnel costs onerous? Have reporting laws been enacted? Does the system provide useful information?

*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 is 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 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. As 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 (i.e., census data), 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 then 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 growing use of computer technology holds promise for improving this attribute.

**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) 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 predictive value may compromise sensitivity and may reduce simplicity. Therefore, these consequences should be considered when recommending modifications.

## 27.5 CASE DEFINITION FOR ACUTE PESTICIDE-RELATED ILLNESS AND INJURY

A case definition is used to identify individuals with a health outcome of interest. 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 earlier in this chapter 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 with vital status statistics involves identifying death certificates that contain ICD-9 E codes specific for accidental pesticide poisoning. The assigned ICD-9 codes are based on data supplied by the health care professional who completed the death certificate. Similarly, data from the BLS and the American Association of Poison Control Centers often involve medical outcome data supplied by the health care provider.

The case definition and the clinical diagnosis serve different purposed. As such, some case definitions may provide a classification that differs from the clinical diagnosis. 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. In contrast, the purpose of the clinical diagnosis is to guide the immediate treatment course for an ill individual.

**National Public Health Surveillance System Case Definition**
The National Public Health Surveillance System (NPHSS) is a conceptual framework for all 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, EPA, National Center for Environmental Health), nonfederal agencies (Council of State and Territorial Epidemiologists, 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 either 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 the health effects. The cases classified into these categories must 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 causal relationship exists between the pesticide exposure and the health effects, a case is classified as "suspicious." This category is assigned when minimal human health effect data are available or 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 abnormal 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 exposure (i.e., knowing what environmental and medical tests should be conducted and what questions to ask); health effects (i.e., 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 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 will be not be total.

There are several reasons for the complexity of the case definition. One is that there is no "gold standard" for pesticide-related illness and injury (i.e., there is no symptom, sign, or test that is definitive for this condition). Therefore, identifying cases of pesticide-related illness and injury require assessment of the 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 classes of pesticides. 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 can be analyzed.

A major strength of the standardized case definition and the standardized variables (described in Section 27.2.2) is that they allow data from participating surveillance systems to be aggregated. This aggregation will enhance knowledge about acute pesticide-related illness and injury. With this knowledge, the goal of surveillance can be 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 National Public Health Surveillance System be used. Regardless of the case definition that is used, all serve the purpose of identifying cases so that appropriate interventions can be targeted.

## 27.6 LIMITATIONS OF PESTICIDE POISONING SURVEILLANCE DATA

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

### 27.6.1 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 morbidity between industrialized and developing nations. Adjusting for relative population size, through the use of rates, emphasizes the disparity (see Tables 27.12 and 27.13).

More refined comparisons require estimates 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, little information is available on unlicensed applicators or on the number of people performing agricultural work. The transient nature of the agricultural workforce in many areas and the fact that some agricultural workers may have entered the country illegally further complicate developing reliable denominators for agricultural pesticide exposure. 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, 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 the EPA 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 in 1990 (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). Although few states require the reporting of pesticide use, New York and California have comprehensive systems for collecting data on pesticide use. Since 1990, California has required agriculturalists and professional applicators to report each pesticide application made in the state. New York has had a similar system in place since 1996. These reports provide, among other details, the identity of the pesticide used, the amount used, the number of acres or other units treated, and the crop or other site to which the pesticide was applied. Collecting all these data is a massive undertaking and provides an enormous amount of information on pesticide usage. 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). It should be noted that 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 statistics on pesticide-related illness, it is important to be mindful of the various factors that can influence the data. These include the method 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 analysis that compares groups based on only some of these factors makes 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 field workers 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 field worker

**Figure 27.6** Strawberry harvesters in a field sprayed with insecticide. (Courtesy of Wayne T. Sanderson.)

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 field workers.

### 27.6.2 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 surveillance systems monitoring conditions related to pesticide exposure may assign different meanings to the terms "pesticide," "exposure," "case," and "related."

In the United States, the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) defines pesticides to include "all substances and mixtures of substances" that "prevent, destroy, repel, or mitigate" any pest. Other statutes clarify that pests include all deleterious organisms, even bacteria, although pharmaceuticals are distinguished from pesticides. Pesticides consequently include sanitizers and disinfectants (e.g., chlorine) along with mothballs, rat baits, weed killers, 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, 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 adverse effects recorded. 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 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 the 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). Additionally, these surveillance systems record the occurrence of burns from pesticide fires, traumatic injuries from pesticide explosions, illnesses resulting from purposeful (i.e., homicidal or suicidal) and accidental ingestion, allergic reactions to pesticide products, and effects associated with inert ingredients. Most controversially, they may 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., health care professionals may report cases that they suspect may be related to pesticide exposure, but for which they are not certain). 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, as many common insecticides are neurotoxic and may elicit anxiety pharmacologically; on the other hand, anxiety unaccompanied by physical 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 27.5).

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, reports are classified according to the National Public Health Surveillance System case definition as "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 with a lower degree of certainty compensates for underreporting. However, this may not be an appropriate remedy for underreporting because the nonconfirmed cases may not be representative of the unreported true cases.

### 27.6.3 LIMITATIONS RELATED TO SENSITIVITY

No surveillance system succeeds in identifying every event of interest. Most surveillance systems capture from 5 to 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, and 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 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 is aware of the need to report the suspected case. Barriers exist at each of these steps that can hamper physician reporting. For example, some populations at greatest risk for pesticide exposure are less likely to seek medical attention except for more severe illness. Those ill individuals who do not seek health care may be detected only after an investigation is conducted into a sentinel case involving a severely ill 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). 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 specific laboratory tests to measure the pesticide, its metabolites, and the effect of the pesticide. Even when tests are available, they are frequently not performed 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 feel are unconfirmed clinically. Additional barriers to physician reporting include protection of a patient who fears loss of a job and ignorance regarding the reporting requirement. Cultural pressures to downplay the hazards of pesticides may prevent a physician residing in an agricultural community from reporting cases.

### 27.6.4 LEGITIMATE USES FOR SURVEILLANCE DATA

With so many difficulties and limitations, attempting surveillance of pesticide-related conditions may seem futile. However, even problematic surveillance data can advance public health when used with appropriate caution. Surveillance data can be 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 a Nicaraguan regional health center that resulted in identification of an epidemic of acute poisonings linked to cholinesterase-inhibiting insecticides. The identification of the epidemic resulted in a prompt education campaign to reduce poisonings from a powdered formulation of carbofuran. In addition, policy recommendations were made to encourage importation of less hazardous pesticides (McConnell and Hruska, 1993). 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 not available when cases are identified retrospectively through surveys of existing data sources.

One is left to wonder whether better surveillance would have reduced the health and financial costs associated with the indoor use of methyl parathion. Since 1984, homes and businesses in at least five different states have been illegally sprayed with methyl parathion. However, 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 ( see Fig. 27.7). Relocations have involved more than 1500 individuals. The cleanup costs for these

**Figure 27.7** Worker conducting methyl parathion remediation to a dwelling in Mississippi. (Courtesy of the U.S. Environmental Protection Agency.)

incidents are estimated at more than $90 million (EPA, 1997a). Little information is available on the health effects associated with these incidents. However, one published report describes methyl parathion–related illness among seven siblings, two of whom had a fatal outcome (CDC, 1984). In addition, another government report summarizing 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 out of 50 (40%) indoor pets 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 EPA and the manufacturers of methyl parathion emulsifiable 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 (EPA, 1997b). As 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.

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 poisoning by organophosphate insecticides to determine if these workers had chronic neurologic sequelae. The workers in this study were identified using surveillance data collected by the California Environmental Protection Agency.

As noted earlier, surveillance data can also be used to examine the magnitude of pesticide-related illness and to assess trends. More work is needed to determine the best approach for combining data from the many different surveillance systems to provide a comprehensive estimate of the magnitude of pesticide-related illness and injury.

### 27.6.5 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 are already underway and an evaluation of their efficacy should be possible in the near future.

One important action is the need to improve training of primary health care professionals. The EPA has launched a new initiative to target health care professionals with educational and training opportunities on pesticide-related health issues (EPA, 1998). 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, and access appropriate resources when necessary. To foster success, these activities should be coupled with the education of workers and consumers on many of these same topics.

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 biological markers of exposure and health effects of pesticides are still primarily research tools. 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). Although much progress has been made in delineating these problems, they have not been satisfactorily resolved (Wilson *et al.*, 1997).

The ability to provide summary data and direct feedback to the medical community, agricultural workers, pesticide manufacturers, commercial pest control firms, and policymakers is a critical aspect of surveillance. Although existing surveillance systems communicate their findings to some degree, this is an area where significant improvements can be made that will strengthen surveillance. The ability to aggregate data across states, combined with increased dissemination of information, will result in a better understanding of the nature of acute pesticide-related illness and injury.

The costs of pesticide-related illness and injury are relatively unknown. Most surveillance systems provide minimal information on the severity of illness that can be used in estimating the cost of illness. Some measures of severity are included in the core standardized variables developed for the SENSOR surveillance system on pesticide-related illness and injury. A matrix for ranking illness severity based on signs, symptoms, time loss from work or regular life activities, and days of hospitalization is currently under development by NIOSH. Much can be learned about the costs of pesticide-related illness and injury if surveillance systems are enhanced to collect measures of illness severity.

## 27.7 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 in identifying health effects related to pesticide exposure. We will 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 populations that are not exposed and, based on these comparisons, evaluate the factors that may cause or influence disease.

### 27.7.1 PRINCIPLES OF EPIDEMIOLOGY

A major premise of epidemiology is that disease is not simply a random occurrence, but 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 the 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, drug use, and weight; and occupational or environmental exposure to various chemical and physical agents.

Diseases 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 respiratory infections caused by bacteria and viruses 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 leukemia caused by benzene and radiation. The time period between initial exposure to a causal agent and disease detection can be divided into the induction period—time between causal action and disease initiation—and the latency period—time between disease initiation and detection. The longer the induction–latency 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, and reproductive problems.

### 27.7.2 EPIDEMIOLOGIC STUDY DESIGNS

Epidemiologists are very rarely able to control the risk factors of study subjects, such as in a randomized controlled trial. Therefore, epidemiology 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 herbicides 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; Mausner and Kramer, 1985).

**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 basic question addressed by a cohort study is: 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 currently and followed forward in time. This is termed a *prospective cohort study*. As the cohort is followed through time, individual exposures and diseases are documented. The rate of disease among those individuals with particular exposures are compared to the rate of disease among the unexposed reference group. Another type of cohort study is the *retrospective cohort study*. In this type of study, a cohort is enumerated in the past (i.e., a cohort that has been exposed some time in the past) and followed up to the present to identify those individuals who develop disease. The disease rates in the

**Figure 27.8** Farmer applying insecticide with a handheld sprayer to control flies on cattle. (Courtesy of Wayne T. Sanderson.)

cohort are compared to those occurring in an unexposed comparison population. This type of study has also been termed a *historical cohort study*.

An example of how a cohort study was used to evaluate the association between pesticide exposures and disease is provided by a study of 20,245 agricultural pesticide applicators in Sweden (Wiklund *et al.*, 1989). The cohort, consisting of all applicators who had been licensed between 1965 and 1976, was followed in the Swedish Cancer Register from the date individuals received their license until 1982 or until 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 number of cancer cases in the Swedish population provided the number of cases that would be expected in the applicator population. A total of 558 malignant tumors was found compared with 649.8 expected, resulting in a statistically significantly decreased standardized incidence ratio (SIR) of 0.86. A finding that reaches *statistical significance* implies that the finding is unlikely to be due to chance. No cancer rates were found to be significantly increased, although the pesticide applicators had higher risk rates for testicular cancer, tumors of the nervous system and endocrine glands, and Hodgkin's disease.

The Swedish pesticide applicator study was a retrospective cohort study; the cohort was enumerated as of some time in the past and then followed over time to estimate cancer rates compared to rates that occurred in the general population. The Agricultural Health Study, which is being conducted in Iowa and North Carolina by the National Cancer Institute, is an example of a prospective cohort study (Alavanja *et al.*, 1996). This is a large study of farmers, commercial pesticide applicators, and their families, who are enrolled and asked to answer questionnaires about their lifestyles, work practices, and exposures at 5-year intervals over a 20-year period. The study includes over 75,000 adult subjects. Pesticide usage information and exposures are being collected in an attempt to relate exposure to disease outcomes. Disease rates are determined at regular intervals for the cohort, and potential risk factors are assessed by the information collected on the questionnaires and contained in disease registry records. Comparisons will be made to data from the National Health and Nutrition Examination Survey (NHANES). In addition, an internal reference population will be used consisting of the unexposed segment of the Agricultural Health Study cohort. As this study is currently ongoing, few results are available.

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 error by study subjects. However, cohort studies are costly, requiring long-term commitment of time and resources, as well as a large sample size. A cohort study may not be possible if data for constructing a retrospective cohort are incomplete. Also, retrospective cohort studies are usually restricted to investigating fatal diseases because nonfatal diseases are often not recorded historically. In contrast, prospective cohort studies may document nonfatal diseases as they occur. The primary cost for conducting cohort studies is in obtaining exposure data on a large number of subjects of which only a small proportion develop the disease of interest.

**Case-Control Study** The basic question addressed by the case-control study is: 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 disease and a control group. Cases may be identified from disease registries, hospital or clinical records, or volunteers. Controls are selected to be similar to the cases with the exception of disease status. Exposure information is developed from existing records or a detailed self-reported questionnaire. This information is used to compare the exposure prevalence between the cases and the controls.

An example of how a case-control study was used to evaluate the association between pesticide exposure and disease is provided by a study of soft-tissue sarcoma, Hodgkin's disease, and nonHodgkin's lymphoma in Kansas (Hoar *et al.*, 1986). All cases of these diseases diagnosed from 1976 to 1982 among white male Kansas residents aged 21 years or older were identified in a state-based cancer registry. Tissue specimens were obtained from the cases to confirm their diagnosis. Each case was matched to three controls who were also white, lived in Kansas, and were within 2 years of the age of the case. Controls were selected either from Medicare files or through telephone calls using random-digit dialing (Waksberg, 1978). The cases, controls, or their next of kin if they were deceased were interviewed by telephone to determine their work practices and use of pesticides and other agricultural chemicals.

Herbicide use was associated with non-Hodgkin's lymphoma [odds ratio (OR), 1.6, 95% confidence interval, 0.9–2.6]. Neither soft-tissue sarcoma nor Hodgkin's disease was associated with pesticide exposure, but non-Hodgkin's lymphoma increased significantly with estimated number of days of herbicide exposure per year.

Case-control studies are particularly useful for studying rare diseases or diseases with a long latency period since first exposure. They 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).

**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, while the exposures of the individuals are also measured at that time. 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 that it may be difficult to determine whether the onset of disease began before or after the exposure. 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. It is these noncurrently employed individuals who 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 (reduced hand dexterity and carpal tunnel syndrome) were likely due to ergonomic stresses experienced by the fumigation workers.

**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 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 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 to guide future, more in-depth research studies.

### 27.7.3 EVALUATING PESTICIDE HEALTH INFORMATION

Information on the toxicity of pesticides can be found in textbooks, in 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 the case at hand. 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 pesticides. As such, skills are 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, and 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.nlm.nih.gov/).

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, save 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 and 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 amount or duration of exposure. It is also important to ensure that investigators minimized bias in the collection of data (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.

It should be noted that none of the conditions described in this section is 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 will not be discussed further. An excellent review of this topic can be found elsewhere (Rothman and Greenland, 1998).

## 27.8 INTERNET AND TELEPHONE RESOURCES FOR PESTICIDE INFORMATION

With the advent of the Internet, important sources of pesticide information are now readily available. Some Internet sites that are useful for pesticide-related illness and injury surveillance follow.

**Bureau of Labor Statistics** This site contains pesticide illness tabulations that supplement those provided in the BLS annual reports. Information is available only for illnesses that result in lost work time. The Web site address is http://stats.bls.gov/oshhome.htm.

**California Environmental Protection Agency** This site is a source for consumer fact sheets and provides access to several useful databases (pesticide product database, chemical ingredient database, and a company information database). The Web site address is http://www.cdpr.ca.gov.

**EXTOXNET** This is a nice 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 Web site address is http://ace.orst.edu/info/extoxnet/ghindex.html.

**National Agricultural Statistics Service, U.S. Department of Agriculture** This site provides information on agricultural pesticide usage. The Web site address is http://www.usda.gov/nass/.

**National Agricultural Workers Survey** This site provides data on U.S. farm workers. Data available at this site may provide useful estimates of the number of crop and livestock workers. These data are available at the county level. The Web site address for NAWS is http://www.dol.gov/dol/asp/public/programs/agworker/naws.htm.

**National Pesticide Telecommunications Network** A cooperative effort of Oregon State University and the EPA, this site provides a toll-free telephone service that provides pesticide information (1-800-858-7378). Information can also be obtained at its Web site (http://ace.orst.edu/info/nptn).

**Pubmed** The medical literature can be searched for information on specific pesticides. Searches can be conducted free-of-charge. The Web site address for PUBMED is http://www.nlm.nih.gov.

**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 Web site address 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/pesticides/safety/healthcare.

**University of Nebraska—Lincoln Institute of Agriculture and Natural Resources** This Web site contains a comprehensive listing of bookmarks for pesticide-related topics. It includes links to sites on all aspects of pesticides (education, databases, health and safety, pesticide manufacturers, laws and regulations, newsletters, and environmental protection) and includes links to other sites mentioned in this section. The bookmarks are verified and updated at least twice a year. This site is a good place to begin a search on a pesticide-related topic. The address for these pesticide-related bookmarks is http://pested.unl.edu/pestbkmk.htm.

## 27.9 CONCLUSIONS

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 TESS, 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 are being made to standardize data collection. Standardization of data collection will facilitate linkage of data across surveillance systems to create a fuller understanding of the acute pesticide-related illness and injury problem. A comprehensive, national surveillance system may be attainable through standardization and information sharing across surveillance systems.

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