

Acute Occupational Pesticide-Related Illness in the US, 1998–1999: Surveillance Findings From the SENSOR-Pesticides Program

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Background Concern about the adverse public health and environmental effects of pesticide use is persistent. Recognizing the importance of surveillance for acute occupational pesticide-related illness, we report on surveillance for this condition across multiple states.

Methods Survey data collected between 1998 and 1999 were obtained from the seven states that conduct acute occupational pesticide-related illness surveillance as part of the Sentinel Event Notification System for Occupational Risks (SENSOR) program. Data were collected by these state programs in a standardized manner and analyzed. Acute occupational pesticide-related illness incidence rates for those employed in agriculture and those employed in non-agricultural industries were also calculated.

Results Between 1998 and 1999, a total of 1,009 individuals with acute occupational pesticide-related illness were identified by states participating in the SENSOR-pesticides program. The mean age was 36 years, and incidence rates peaked among 20–24 year-old workers. The overall incidence rate was 1.17 per 100,000 full time equivalents (FTEs). The incidence rate among those employed in agriculture was higher (18.2/100,000 FTEs) compared to those employed in non-agricultural industries (0.53/100,000 FTEs). Most of the illnesses were of low severity (69.7%). Severity was moderate in 29.6% of the cases, and high in four cases (0.4%). Three fatalities were identified. Insecticides were responsible for 49% of all illnesses.

Conclusions Surveillance is an important tool to assess acute pesticide-related illness, and to identify associated risk factors. Our findings suggest that these illnesses continue to be an important occupational health problem, especially in agriculture. As such, greater efforts are needed to prevent acute occupational pesticide-related illness. *Am. J. Ind. Med.* 45:14–23, 2004. Published 2003 Wiley-Liss, Inc.[†]

KEY WORDS: pesticides; poisoning; agricultural workers' diseases; insecticides; herbicides; incidence; risk

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INTRODUCTION

Pesticides are substances used to destroy, mitigate, or repel pests, and their usage is widespread in the US. In a typical year, about 1.24 billion pounds of conventional pesticides are used [Donaldson et al., 2002], which represents 22% of the entire worldwide use of these pesticides. Over 16,000 pesticide products are registered for use in the US, and these contain one or more of the 674 registered active ingredients.

Although pesticides serve many useful purposes, the public continues to express concerns about the adverse public health and the environmental effects of pesticides. Ensuring safe use of pesticides, especially in the agricultural sector, can be difficult. There are many reasons for this. Although pesticide products go through an extensive battery of testing prior to being registered by the US Environmental Protection Agency (EPA), the testing protocol cannot address the entire spectrum of environmental conditions, mixtures of chemicals, chronic exposure patterns, and human susceptibilities. Given these testing limitations, it is possible that adverse health effects could result even when pesticide products registered by the EPA are used in accordance with label instructions. In addition, the EPA often delegates pesticide use enforcement to state departments of agriculture. These state agencies face barriers (e.g., insufficient personnel) to inspect pesticide-using worksites and farms frequently enough to ensure safe pesticide usage. Finally, because agricultural workers rarely belong to unions, are often non-US citizens, and often have poor English language skills, they may be very reluctant to raise health and safety concerns.

Surveillance for acute pesticide-related illness can serve many purposes. It can promptly identify pesticide problems by both serving as an early warning system of any unexpected health effects not observed during manufacturer testing, and detecting pesticide problems caused by non-compliance with pesticide regulations. In addition, surveillance data are useful for assessing both the magnitude of acute pesticide-related illness and poisoning trends over time. Furthermore, risk factors identified through surveillance or follow-up investigations can be targets for effective interventions.

The National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention (NIOSH/CDC), through the Sentinel Event Notification System for Occupational Risks (SENSOR) program has provided technical and financial support for state-based surveillance of acute occupational pesticide-related illness and injury since 1987. The SENSOR-pesticides program is also partially funded by the EPA. This report summarizes the SENSOR-pesticides surveillance data for 1998 and 1999. It includes data from all but one of the eight states with a pesticide poisoning surveillance program (Washington State was not included because their program used a different case

definition and variables during the years summarized in this article). Although previous reports have described findings for a single state [Maddy et al., 1990; Mehler et al., 1992; Schnitzer and Shannon, 1999; Das et al., 2001a], this is the first report on acute occupational pesticide-related illness incidence across multiple states.

MATERIALS AND METHODS

Data from 1998 and 1999 were collected from the seven states participating in the SENSOR-pesticides program during those years. Cases were provided by the California Department of Health Services, the Texas Department of Health, the Oregon Department of Human Services, the New York State Department of Health, the Florida Department of Health, the Louisiana Department of Health and Hospitals (only 1999 data were available), and the Arizona Department of Health Services. These states began using a common standardized case definition and classification scheme to evaluate reports in 1998.

Each of the participating states obtains case reports from many different sources. All of these states require physician reporting of pesticide-related illness cases [Calvert et al., 2001]. Other sources of case reports vary by state and include poison control centers, emergency medical services, medical laboratories, other health care providers, clinics, worker representatives (e.g., Migrant Legal Aid, selected community contacts, co-workers, friends, relatives), employers and state agencies with jurisdiction over pesticide use (e.g., departments of agriculture and structural pest control boards). States also routinely review other data sources to identify additional potential cases (e.g., workers' compensation claims, hospital discharge data, news reports, and death certificates). In addition, some states accept self-reports.

Once a report is received, the states determine whether the subject was symptomatic and whether the involved chemical is a pesticide. If so, attempts are made to interview the poisoned subject or their proxy to obtain details on the poisoning event, and medical records are requested. Besides identifying, classifying, and tabulating pesticide poisoning cases, the states periodically perform in-depth investigations of pesticide-related events and develop interventions aimed at particular industries or pesticide hazards.

The information collected by the state agencies in a standardized manner includes date of illness, information on the ill individual (gender, race, age, signs, symptoms, industry, and occupation) whether the illness occurred as a result of workplace exposures, identification of the pesticide(s) that produced the illness, activity of the individual when exposed, type of exposure (e.g., drift, direct spray, indoor air exposure, or exposure to a spill or leaking container), biological monitoring information (i.e., cholinesterase testing and results, and whether other biological testing was performed), and whether personal protective equipment

(PPE) was used. For this analysis, PPE included goggles, faceshield, gloves (cloth, leather, rubber, or synthetic), rubber/chemically resistant boots, chemically resistant clothing, or a respirator.

Only cases involving occupational exposures are included in this article. A case is classified as occupational if the pesticide exposure occurred while at work. All other cases are classified as non-occupational. Suicides and attempted suicides are classified as non-occupational.

The EPA toxicity category was sought for all pesticide products associated with the illness event. The EPA classifies all pesticide products into one of four toxicity categories based on established criteria (40 CFR Part 156). Pesticides with the greatest toxicity are placed in category I, and those with the least are in category IV. In those instances when only the pesticide active ingredient associated with the illness event was available, and not the pesticide product, toxicity category information was not available. Pesticide products are classified into toxicity categories, but not active ingredients.

Case Definition

The case definition for acute pesticide-related illness and injury was finalized in 1998 [Calvert et al., 2001]. A full description of the case definition is beyond the scope of this article but is available elsewhere [CDC, 2000a]. Briefly, information in three areas is required: pesticide exposure, health effects, and toxicological evidence supporting an association between exposure and effect. A case of pesticide-related illness or injury is classified into one of the following categories: definite, probable, possible, or suspicious. The specific classification category applied to a given case depends on the certainty of exposure, whether health effects consisted of signs observed by a health care professional versus symptoms reported by the poisoned subject, and the extent to which the health effects were consistent with the known toxicology of the pesticide product. The health department reporting the case classified it.

Illness severity was determined for each case. A detailed description of the severity index used to assign severity is also beyond the scope of this article but is available [CDC, 2001]. Briefly, a case of pesticide-related illness or injury is classified into one of the following categories: low, moderate, high, or death. Information considered when assigning severity includes signs and symptoms, whether health care was sought, length of hospital stay, and work days lost due to the illness. A *low severity illness or injury* consists of minimally bothersome health effects that generally resolve rapidly. A *moderate severity illness or injury* consists of non-life threatening health effects that are more pronounced, prolonged, or of a systemic nature compared to a low severity illness. A *high severity illness or injury* consists of life threatening health effects or those that result in significant

residual disability or disfigurement. *Death* is the severity category assigned to fatalities resulting from pesticide exposure. Because the severity index was not finalized until 2001, one of the authors (G.M.C.) assigned severity to all of the cases.

Data Analysis

SAS software was used for data management and chi-square statistical analyses of categorical data. Incidence rates were calculated. The numerator was the total number of illness cases. The denominator was obtained from the full time equivalent (FTE) estimates derived from the Current Population Survey conducted between 1998 and 1999 [Bureau of Labor Statistics, 2001]. Average annual incidence rates were calculated for those employed in agriculture (Bureau of the Census industry codes [BOC] = 010–030), and for those employed in non-agricultural industries (all other BOC industry codes). Incidence rates were also calculated for various age groups, for males and females, and for each of the participating states. Because only one occupational case was identified by Louisiana, it was not included in the rate analyses. Incidence rate ratios (IRR) were derived by taking the ratio of relevant rates, and confidence intervals were calculated [Rothman, 1986].

RESULTS

Between 1998 and 1999, a total of 1,009 cases of acute occupational pesticide-related illness were identified by the SENSOR-pesticides program. There were 523 cases in 1998 and 486 cases in 1999. These cases fell into the following classification categories: definite = 98 (10%), probable = 258 (26%), possible = 546 (54%), and suspicious = 107 (11%). The incidence rate was 1.17 per 100,000 FTEs (Table I).

The mean age was 36 years (range 13–73 years). Incidence rates peaked among 20–24-year-old workers and decreased gradually with increasing age (Fig. 1). Information on race/ethnicity was available for 366 cases (36%). Of these, 198 (54%) were Caucasian, 125 (34%) were Hispanic, 34 (9%) were black, and 9 (2%) were classified as “other” race. Males accounted for 63% of the cases. The incidence rate among males was slightly higher compared to females (male = 1.25/100,000 FTEs, female = 1.04/100,000 FTEs, IRR = 1.20, 95% confidence interval (CI) = 1.06, 1.36). Median latency between exposure date and date of report to the state health department was 13 days (range 0–783 days). A total of 50% of the cases were exposed in the summer months (June through September).

The industry where the case was employed was available for 911 cases. A total of 469 cases (51%) were employed in agriculture and 58% were exposed in the summer months. The incidence rate among those employed in agriculture

TABLE I. Distribution of Cases of Acute Occupational Pesticide-Related Illness, Full Time Equivalent (FTE) Estimates and Incidence Rates by Industrial Sector and State, 1998–1999; SENSOR-Pesticides Program

State ^a	Industrial sector (BOC codes)								
	All			Agricultural (010–030)			Non-agricultural (all other codes)		
	N	FTE estimates ^b	Incidence rate ^c	N	FTE estimates ^b	Incidence rate ^c	N	FTE estimates ^b	Incidence rate ^c
Arizona	23	4,336	0.53	19	135	14.1	2	4,201	0.05
California	588	29,846	1.97	343	1,109	30.9	229	28,737	0.80
Florida	88	13,769	0.64	48	335	14.3	38	13,434	0.28
New York	32	15,796	0.20	8	192	4.2	24	15,604	0.15
Oregon	47	3,140	1.50	8	123	6.5	39	3,017	1.29
Texas	229	19,420	1.18	42	678	6.2	109	18,742	0.58
Total	1,007	86,307	1.17	468	2,572	18.2	441	83,735	0.53

BOC, Bureau of the Census industry codes.

^aExcluded from this table were two cases: the one Louisiana case, and a case involving an adolescent under 15 years of age (denominator data is not available for those under 15 years of age). In addition, industrial sector information was not available for 98 cases. These 98 cases are included only in the columns that describe all cases.

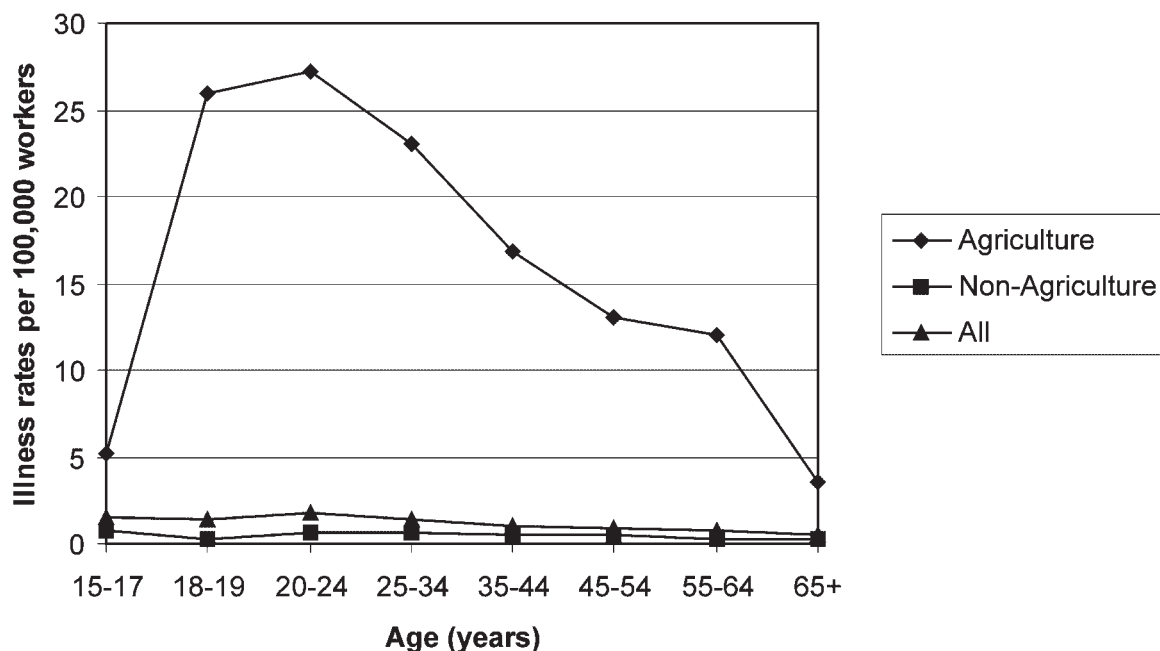
^bIn thousands of FTEs.

^cPer 100,000 FTEs.

was 18.2/100,000 FTE (Table I). Interestingly, although 70% of the agricultural cases were male, the incidence rate among males (15.6/100,000 FTEs) was significantly lower than that among females (29.7/100,000 FTEs) (IRR = 0.53, 95% CI = 0.43, 0.65). As was found for all industries combined, the incidence rate among agricultural cases was highest among 20–24-year-old workers (Fig. 1). The occu-

pation of most cases employed in agriculture was farm worker (70%).

A total of 442 cases were employed in non-agricultural industries. These cases were almost evenly split between males (234 cases, 53%) and females (205 cases, 46%) (3 cases had unknown gender). The incidence rate among those employed in non-agricultural industries was 0.53/100,000

**FIGURE 1.** Acute occupational pesticide-related illness rates by age and industry, 1998–1999; SENSOR-pesticides program.

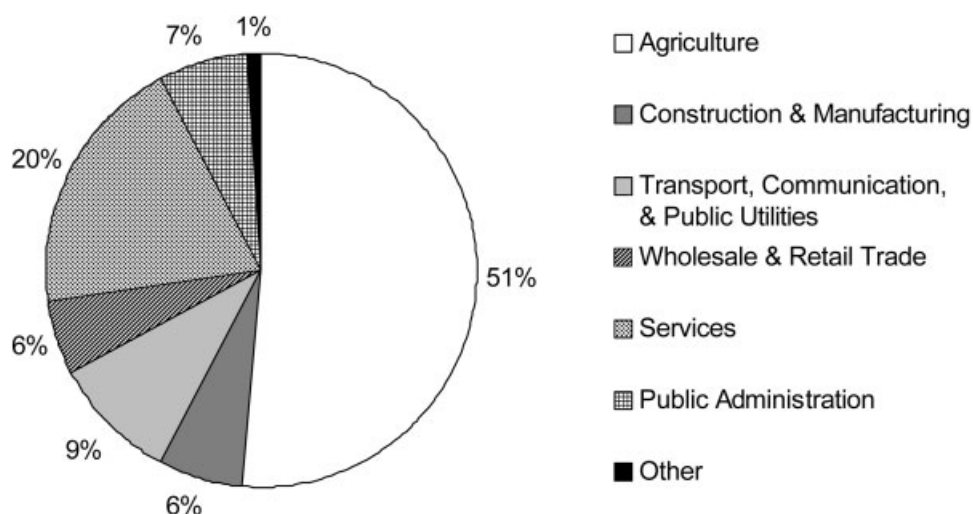


FIGURE 2. Acute occupational pesticide-related illnesses by industry category, 1998–1999; SENSOR-pesticides program. Agriculture (51%); Construction and Manufacturing (6%); Transport, Communication and Public Utilities (9%); Wholesale and Retail Trade (6%); Services (20%); Public Administration (7%); Other (1%).

FTEs, and was significantly lower among males (0.48/100,000 FTEs) compared to females (0.58/100,000 FTEs) (IRR = 0.83, 95% CI = 0.68, 0.99). The incidence rate was highest among 15–17 year olds (0.76/100,000 FTEs) and decreased with increasing age (Fig. 1). A total of 40% of the non-agricultural cases (177 cases) were employed in the services sector (Fig. 2), and 21 of these were employed in pest control.

Information on the number of cases identified by each state is provided in Table I. California identified the most cases and had the highest overall incidence rate and the highest agricultural incidence rate.

Information on the pesticides responsible for acute occupational pesticide-related illness is provided in Table II. Insecticides were responsible for 49% of the illnesses. Among the insecticides, organophosphates (n = 233), carba-

mates (n = 76), pyrethroids (n = 55), and pyrethrins (n = 46) were most commonly responsible. A total of 160 separate active ingredients were identified as potentially responsible for one or more illness cases. Among these active ingredients, Table III provides the 16 most commonly reported. These 16 active ingredients are thought to be responsible for 563 (57%) of the 996 cases having active ingredient information available.

The active ingredient responsible for the largest number of cases was sulfur. Sulfur is used as an acaricide and fungicide on a variety of crops, and is irritating to the skin, eyes, and respiratory tract. All but one of the sulfur-associated cases were exposed in California. Of the 78 cases, 67 were employed in agriculture and most were farm workers (n = 58) performing routine work activities that did not involve pesticide application. Sulfur was often used on

TABLE II. Acute Occupational Pesticide-Related Illness by Pesticide Functional Class and Severity, 1998–1999; SENSOR-Pesticides Program

Pesticide functional class	Severity category				Total
	Low	Moderate	High	Death	
Insecticides	359 (72%)	132 (27%)	3 (1%)	0	494 (49%)
Herbicides	55 (65%)	29 (35%)	0	0	84 (8%)
Fungicides	37 (70%)	16 (30%)	0	0	53 (6%)
Fumigants	66 (57%)	49 (43%)	0	0	115 (11%)
Disinfectants	29 (69%)	13 (31%)	0	0	42 (4%)
Insecticides + fungicides	60 (81%)	13 (18%)	1 (1%)	0	74 (7%)
Other ^a	23 (77%)	4 (13%)	0	3 (10%)	30 (3%)
Multiple ^b	74 (63%)	43 (37%)	0	0	117 (12%)
Total	703 (69.7%)	299 (29.6%)	4 (0.4%)	3 (0.3%)	1,009

^aThis category includes plant growth regulators, insect growth regulators, wood treatment products, preservatives, and insect repellants.

^bPesticide product was classified into more than one functional class.

TABLE III. List of the 16 Pesticide Active Ingredients Thought to be Responsible for the Largest Number of Acute Occupational Pesticide-Related Illnesses, and the Type of Exposure, 1998–1999; SENSOR-Pesticides Program

Active ingredient (US EPA chemical code)	N	Type of exposure ^a					
		Drift (%)	Surface (%)	Indoor air (%)	Spray (%)	Contact (%)	Unknown (%)
Sulfur (77501)	78	9	13	5	14	22	37
Malathion (57701)	56	34	9	14	25	14	4
Chlorpyrifos (59101)	51	29	0	18	8	10	35
Methyl bromide (53201)	49	0	2	2	4	82	10
Pyrethrins (69001)	49	0	0	69	4	8	19
Carbofuran (90601)	47	0	74	0	4	17	5
Diazinon (57801)	41	34	0	20	10	20	16
Propetamphos (113601)	39	0	0	95	0	0	5
Metam-sodium (39003)	38	71	0	0	5	13	11
Glyphosate (103601)	24	8	4	0	29	25	34
Propargite (97601)	20	30	0	0	10	5	55
Copper (metallic) (22501)	16	63	0	0	31	0	6
Copper sulfate (24401)	15	0	7	0	13	40	40
Dimethoate (35001)	14	50	0	0	21	7	22
Methoprene (105401)	13	15	0	85	0	0	0
Permethrin (109701)	13	23	0	23	8	23	23

^aType of exposure indicates how the pesticide exposure occurred. This information was not available for 31% of the cases (312/1,009). Drift, exposure by off target deposition during pesticide application; surface, exposure by contact with treated surface; indoor air, exposure via indoor air contamination; spray, exposure by direct spray of the pesticide; contact, exposure by spill, leaking container, or other direct contact.

beverage crops (e.g., wine grape vineyards) ($n = 27$) and on other small fruit crops (e.g., table grapes) ($n = 11$). As expected, health effects most often involved the skin ($n = 45$, 58%), eyes ($n = 32$, 41%), and respiratory tract ($n = 22$, 28%). Severity for these sulfur-associated cases was low for most ($n = 64$, 82%), moderate for 13 (17%) cases, and high for one (1%).

Overall, most of the acute occupational pesticide-related illnesses were of low severity (69.7%) (Table II). The three fatalities involved Vietnamese shrimpers whose bodies were found in their fishing vessel off the Florida coast. They had used sodium metabisulfite to preserve their catch. Sulfur dioxide gas, acutely toxic to the respiratory tract, is liberated when sodium metabisulfite is mixed with water. The medical examiner concluded that these three deaths were due to sulfur dioxide exposure.

Among the four cases with high severity was a 34-year-old female hospital housekeeper who was exposed to an organophosphate (propetamphos) and a pyrethroid (cyfluthrin) after entering a recently treated surgical unit, and was hospitalized for 4 days with dyspnea, fasciculations, dizziness, and vomiting. Another was a 27-year-old pesticide applicator working in agriculture who was sprayed with malathion and dimethoate and developed pulmonary edema. An additional high severity case involved a 26-year-old female bus driver who was exposed to sulfur when it drifted from a nearby field which was being sprayed. She ex-

perienced dyspnea, and hypoxemia that resulted in a 4-day hospitalization. Finally, a 47-year-old manager of a hardware and feed store where pesticides were sold, and who was also exposed to pyrethrins/pyrethroids at his home, developed hypersensitivity pneumonitis that required a 13 day hospitalization.

A total of 850 (84%) cases were evaluated and treated by a health care professional, and of these, 58 were hospitalized for a median of 1 day (range 1–13 days). An additional 70 cases (7%) received advice only from a poison control center, and the remaining cases either received no medical care (49, 5%), unknown care (31, 3%), or other, unspecified care (9, 1%). For all pesticides combined, the most commonly observed effects involved the nervous system (58%), the gastrointestinal system (49%), the respiratory system (48%), the eye (39%), and the skin (30%).

Laboratory testing data were obtained on a low proportion of cases. Among the 332 subjects poisoned by cholinesterase-inhibiting insecticides, cholinesterase tests were performed on 95 (29%), not performed on 70 (21%), and this information was unknown for 167 (50%). Among the 95 who were tested, 15 (16%) had an abnormal result (14 had an abnormal result compared to the laboratory reference range and 1 had an abnormal result compared to his baseline cholinesterase activity), 53 were normal, and 27 had an unknown result. Information on whether other biological testing was performed was available on 646 subjects. Of these,

only 77 (12%) had such testing performed. Most of this testing was among those poisoned with carbamates (37/77, 48%), fumigants (24/77, 31%), and organophosphates (10/77, 13%). Standardized information is not collected on the type of other biological testing performed, nor on the test results. However, 31 of the tested carbamate cases were exposed in the same outbreak and had urinary carbofuran metabolites measured [CDC, 1999a].

For most cases, the pesticide exposure occurred while the individual was performing routine work activities that did not involve pesticide application (673/1,009; 67%). For 25% (255/1,009) of the cases, the exposure occurred while the individual was involved with the pesticide application process (i.e., applying, mixing/loading, transport/disposal, or equipment repair/maintenance). The proportion of cases exposed during the pesticide application process was greater among those employed in agriculture (153/469; 33%) versus those employed in non-agriculture (83/442; 19%) ($P < 0.001$). The activity of the individual at the time of exposure was unknown for the remaining cases (81/1,009; 8%). As would be expected, among those exposed during the pesticide application process, exposure often occurred by direct spray (59/255; 23%) or by contact from a spill or leaking equipment (79/255; 31%). In contrast, among those who were not applying pesticides at the time of exposure, the exposure was often by drift (153/673; 23%) or by exposure to indoor air contaminated with pesticides (188/673; 28%). For 26% of the cases (258/1,009), information on how the exposure occurred was not available.

Information on the target of the pesticide was available for 714 cases (71%). A large proportion were not related to an intended pesticide application, but instead occurred after a spill, from exposure to a leaking pesticide container, or during emergency response (134/714; 19%). Of these, 14 cases were health care workers who were poisoned after exposure to pesticide-contaminated patients. For exposures related to an intended pesticide application, the target of the pesticide depended on whether or not the worker was employed in agriculture. Most of the non-agricultural cases arose from treatment of building structures (178/297; 60%) and from landscaping treatments (33/297; 12%). Among the cases that occurred among agricultural workers, the intended target of the pesticides were often fiber crops (e.g., cotton) (57/291; 20%), beverage crops (e.g., wine grapes) (40/291; 14%), landscaped areas (33/291; 11%), soil (i.e., to disinfect for fungi, nematodes, and insects) (21/291; 7%), other small fruit crops (e.g., berries, table grapes) (18/291; 6%), and undesired plants (i.e., the undesired plant was the *only* target) (14/291; 5%).

EPA toxicity category information was available for 420 (42%) of the affected individuals. A total of 209 (50%) were exposed to toxicity category I pesticides, 98 (23%) to category II pesticides, and 113 (27%) to category III pesticides. Those employed in agriculture were more likely to be

exposed to toxicity category I or II pesticide products (171/204; 84%) compared to those employed in non-agricultural industries (126/187; 67%, $P < 0.01$).

For only 456 cases was information on PPE use available. Of these, PPE was used by 140 (31%). Those involved with the pesticide application process were more likely to wear PPE (56/85; 66%) compared to those performing routine work activities that did not involve pesticide application (83/368; 23%) ($P < 0.001$). The PPE most often worn by those involved with pesticide application included rubber/synthetic gloves ($n = 21$), chemical goggles/faceshield ($n = 24$), and chemically resistant clothing ($n = 22$). The PPE most often worn by those performing routine work activities included dust masks/disposable respirators ($n = 81$) and cloth or leather gloves ($n = 32$). The proportion of applicators who used PPE was greater among those employed in agriculture (agriculture = 79%; non-agriculture = 51%, $P < 0.01$). Illness severity was found not to be associated with use of PPE ($P = 0.07$), but those who wore PPE were more likely to be exposed to toxicity category I or II pesticides (PPE worn = 83%; PPE not worn = 69%, $P = 0.02$). The fact that the subjects were poisoned despite using PPE suggests that the PPE was either inappropriate or incorrectly used.

As for involvement of enforcement agencies, this information was available only for 157 cases. Of these, violations of pesticide rules and regulations were identified in 71 cases. Most violations pertained to Federal Insecticide, Fungicide, and Rodenticide Act violations ($n = 65$), including non-compliance with the pesticide product label ($n = 44$), and worker protection standard violations ($n = 20$). A total of 24 cases were associated with Occupational Safety and Health Administration standard violations. Enforcement agencies investigated an additional 63 cases but no violations were cited. Several cases were not investigated by enforcement agencies, either because the case subject refused ($n = 10$), or because enforcement agency involvement was not applicable ($n = 11$). Enforcement agency findings were pending in two cases. Neither agricultural employment ($P = 0.36$) nor illness severity ($P = 0.36$) were associated with a violation.

Case reports were received from many different sources. The three leading report sources were other government agencies (e.g., the state department of agriculture and county health departments) (35%), workers' compensation (32%), and poison control centers (20%). The remaining cases were reported by a variety of sources, including health care professionals (5%) and employers (3%). The principal report source varied across states. In Arizona, New York, and Oregon other government agencies provided most reports, California's principal report source was workers' compensation, Texas' data were largely from poison control centers, and in Florida it was through employer reports. Among the three leading report sources, median latency between

exposure date and date of report to the state health department were lowest for other government agencies at 9 days. Median latency for workers' compensation was 14 days and for poison control centers was 126 days.

DISCUSSION

When used properly, pesticides offer a variety of benefits to society. They increase crop yields, preserve foodstuffs, and combat pathogenic and nuisance insect infestations. However, pesticides are also among the few chemicals that are specifically designed to kill and cause harm. Because society allows these chemicals to be disseminated into the environment, society incurs a responsibility to ensure their safe use and to survey for associated health effects. One method to assess the public health impact of pesticide use is through acute pesticide poisoning surveillance. Acute pesticide poisoning surveillance has been endorsed by many organizations and federal government authorities [CSTE, 1999; GAO, 2000; NIOSH, 2001; Pew Environmental Health Commission, 2001].

The data generated by the SENSOR-pesticides program can be useful for identifying potentially relevant risk factors. For example, those employed in agriculture were found to have a far greater incidence rate for acute occupational pesticide-related illness compared to those employed in non-agricultural industries. This higher rate may be partially explained by the high usage of pesticides in agriculture. During 1998–1999, the agricultural industry used 79% of the total US volume of pesticide active ingredient [Donaldson et al., 2002]. In contrast, agricultural employment accounted for only 3% of FTEs in the US (Table I). Furthermore, within agriculture, insecticides (36%), fumigants (16%), and products containing both insecticides and fungicides (13%) were responsible for a large proportion of illnesses. These pesticides could be a focus of intervention efforts, especially on farms producing fiber crops (e.g., cotton) and beverage crops (e.g., wine grapes). In addition, interventions targeting farm workers should be considered as these workers accounted for most agricultural illnesses. As affected farm workers were often performing routine work activities that did not involve pesticide application (215/329; 65%), frequently through exposure to pesticide drift (71/215; 33%) or contact with a treated plant or other surface (45/215; 21%), these activities are other important intervention targets. This report and other evidence [Arcury et al., 2001] suggest poor compliance with the Worker Protection Standard, suggesting the need to enhance enforcement, and employer and worker awareness of this standard.

Although identification of poisoning risk factors is useful for targeting intervention efforts, the limited resources of state surveillance systems precluded obtaining all relevant risk factor information. For each illness case, attempts are made to collect data on a large number of variables (i.e., 148

variables). Securing this information is labor- and resource-intensive. Although improvements are needed to ensure that this information is collected on a higher proportion of cases, this cannot occur without providing additional resources to state surveillance programs.

In addition to assessing magnitude and identifying risk factors, the SENSOR-pesticides program has identified many emerging pesticide problems [CDC, 1999a,b,c, 2000b, 2003; Das et al., 2001b; Calvert et al., 2003]. Detection of these problems has resulted in efforts to prevent their recurrence. For example, after illnesses were found to be associated with the pesticides used to eradicate Medfly infestations, additional resources were employed to successfully prevent subsequent Medfly infestations at least through mid-2003. The findings from this study also supported the need for public notification requirements in Medfly eradication and mosquito abatement programs [CDC, 1999c, 2003]. Another emerging pesticide problem that was detected involved illnesses associated with automatic insecticide dispensers [CDC, 2000b]. Following dissemination of the findings of this report, EPA requested that the registrants of these products respond to the CDC recommendations for use modification and warning labels.

Our surveillance findings have led to efforts to raise awareness of pesticide toxicity among workers and health care professionals. Intervention efforts aimed at workers include creation of pesticide safety information materials (e.g., a novella and health promotion messages) for Spanish-language radio transmission and distribution of brochures that summarize pesticide safety messages and trinkets (e.g., key chains) that deliver poison control and health department contact information. To improve the ability of health care professionals to recognize, manage, and prevent pesticide-related illnesses, SENSOR-pesticides representatives assisted in the development of a strategic plan to expand and enhance relevant educational opportunities and resources [NEETF, 2002]. In addition, surveillance programs conduct outreach to clinicians to raise awareness of pesticide issues. Finally, surveillance findings have also been a spring board for research projects including one to enhance laboratory reporting of cholinesterase measurements and another examining the neurobehavioral effects associated with acute pesticide-related illness.

Several limitations with this surveillance data should be noted. Although the active ingredients provided in Table III were likely responsible for the reported pesticide-related illness, this may not have always been the case. This is because on average, each poisoned subject was exposed to 1.5 active ingredients. In those instances where the case was exposed to multiple active ingredients, it is possible that only one of the active ingredients produced the illness. Furthermore, pesticide products also may contain solvents and other inert ingredients, some of which may produce illness. However, since identification of inert ingredients present in

pesticide products often is not available, attribution of illness to these ingredients rarely can be made.

Other limitations involve the incidence rates. These rates are likely to be underestimates due to one or more factors [Azaroff et al., 2002]. Many individuals with pesticide-related illness are never ascertained because they neither seek medical care nor call appropriate authorities. Furthermore, because the signs and symptoms of acute pesticide-related illness are not pathognomonic, and because most health care professionals receive little instruction on this illness, many who seek medical care may not be correctly diagnosed. Even among those who are correctly diagnosed, many are not reported to state surveillance systems, despite the fact that each of the participating states has mandatory reporting of occupational pesticide-related illness [Calvert et al., 2001]. Finally, illness rates among those exposed to pesticides are not available because the number of workers exposed to pesticides is unknown. Instead, our denominators include all workers employed in a given industry. Because of underascertainment of cases and because not all of those included in the denominator are at risk for pesticide poisoning, the rates we provide must be considered minimum estimates of the true magnitude of the problem.

Rapid identification of a toxic agent can be critical to the diagnosis of pesticide poisoning. However, with the exception of tests for cholinesterase-inhibiting insecticides, biological markers of exposure have either not been developed or are not widely available. Enhancing laboratories to measure toxic chemicals in the body, either unchanged or metabolically altered, will both strengthen our ability to diagnose acute pesticide-related illness and aid in the timely recognition of toxin-related outbreaks.

Although the incidence rates for acute occupational pesticide-related illness were highest in California, this finding should be interpreted with caution. This finding does not necessarily mean that pesticide exposures are more hazardous or more prevalent in California; more likely it has to do with better case reporting. Whereas 53% of the California cases were identified through workers' compensation reports, only two other states, Oregon and Texas, received workers' compensation reports and in these states these reports accounted for only 2% and 1%, respectively. Clearly, workers' compensation is an important source of case reports, especially when the workers' compensation system is designed and utilized as in California. Other states with relatively high incidence rates were able to exploit other report sources. For example, in Texas 76% of cases were reported by poison control centers, whereas poison control centers accounted for only 4% of cases in the remaining states. An earlier finding that state surveillance systems capture only 14% of cases identified by poison control centers [Calvert et al., 2003] suggests the need for better poison control center reporting in all states. The relatively high incidence rate in Oregon may be attributed to the success

of its interagency board, the Pesticide Analytical Response Center (PARC). PARC consists of representatives from various state agencies with jurisdiction over pesticides, health, and the environment. PARC representatives periodically meet to review pesticide incidents, coordinate investigations, and develop prevention strategies.

Data from the two oldest pesticide poisoning surveillance systems in the US were not included in these analysis. They were initiated in the early 1970s and are currently maintained by the California Department of Pesticide Regulation (CDPR) and the Washington State Department of Health. Both of these programs were using case definitions and variables that differed from SENSOR-pesticides in 1998–1999, and this precluded inclusion of their data. However, these older programs appear to have more success with case ascertainment. For example, during 1998–1999, the CDPR alone identified 909 cases of acute occupational pesticide related illness (Louise Mehler, CDPR, unpublished communication, August 23, 2002).

Clearly, improvements in case ascertainment can be made in all states. To maximize case ascertainment, surveillance programs can optimize use of workers compensation data, poison control center data, and data from other state agencies with enforcement jurisdiction over pesticides. To improve poison control center reporting, SENSOR-pesticides is funding modifications to a software program used by most poison control centers that will allow prompt electronic reporting of eligible reports. The SENSOR-pesticides program also encourages state surveillance systems to obtain access to submitted workers' compensation claims data and to foster effective collaborations with other state agencies having jurisdiction over pesticides.

The case definition used for acute pesticide poisoning surveillance is relatively complex. There are several reasons for this complexity, including the need for sufficient flexibility to handle the large number of registered active ingredients and pesticide products, and their associated toxic effects. For various reasons, relatively few cases met the strict criteria required for a "definite" classification. However, given the degree of evidence required to classify a case into one of the other three classification categories, we think the number of false-positive cases is minimal. Unfortunately, because there is no gold standard for the diagnosis of acute pesticide-related illness, it is impossible to determine the case definition's sensitivity, specificity, and predictive value positive. Despite the limitations of the case definition, it provides an objective, standardized approach for assessing the pesticide exposure–health effect relationship.

A final limitation is that this article provides information on acute illnesses associated with pesticide exposure only. Although pesticides are also associated with chronic illnesses (e.g., non-Hodgkin's lymphoma is associated with 2,4-dichlorophenoxyacetic acid (2,4-D) exposure [Dich et al., 1997] and chronic neurological effects are associated with

acute organophosphate poisoning [Eyer, 1995]), the difficulty with attributing these to pesticide exposures precludes conducting surveillance of chronic pesticide-related illnesses. Estimating the extent of chronic pesticide-related illnesses would require applying attributable risk proportions to data from national surveys.

In conclusion, surveillance is an important tool. It can identify emerging pesticide problems, estimate the magnitude of acute occupational pesticide-related illness and injury, and identify associated risk factors. Although improvements can be made to the SENSOR-pesticides program, we are aware of no better national surveillance system for acute occupational pesticide-related illness and injury. Additional support for this surveillance system will improve the prompt identification of pesticide problems and will help to ensure that prevention efforts are effectively targeted.

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REFERENCES

- Arcury TA, Quandt SA, Cravey AJ, Elmore RC, Russell GB. 2001. Farm worker reports of pesticide safety and sanitation in the work environment. *Am J Ind Med* 39:487–498.
- Azaroff LS, Levenstein C, Wegman DH. 2002. Occupational injury and illness surveillance: Conceptual filters explain underreporting. *Am J Pub Health* 92:1421–1429.
- Bureau of Labor Statistics. 2001. Current Population Survey 1988–1998 microdata files. Washington DC: US Department of Labor, Bureau of Labor Statistics.
- Calvert GM, Sanderson WT, Barnett M, Blondell JM, Mehler LN. 2001. Surveillance of pesticide-related illness and injury in humans. In: Krieger R, editor. *Handbook of pesticide toxicology*, 2nd edn. San Diego: Academic Press. pp 603–641.
- Calvert GM, Mehler LN, Rosales R, Baum L, Thomsen C, Male D, Shafey O, Das R, Lackovic M, Arvizu E. 2003. Acute pesticide-related illnesses among working youths, 1988–1999. *Am J Pub Health* 93:605–610.
- CDC. 1999a. Farm worker illness following exposure to carbofuran and other pesticides—Fresno County, California, 1998. *MMWR* 48:113–116.
- CDC. 1999b. Illnesses associated with occupational use of flea-control products—California, Texas, and Washington, 1989–1997. *MMWR* 48:443–447.
- CDC. 1999c. Surveillance for acute pesticide-related illness during the Medfly Eradication Program—Florida, 1998. *MMWR* 48:1015–1018, 1027.
- CDC. 2000a. Case definition for acute pesticide-related illness and injury cases reportable to the National Public Health Surveillance System. Cincinnati, Ohio: US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health. Available: <http://www.cdc.gov/niosh/pestsrv/> [accessed 13 January 2003].
- CDC. 2000b. Illnesses associated with use of automatic insecticide dispenser units—Selected states and United States, 1986–1999. *MMWR* 49:492–495.
- CDC. 2001. Severity index for use in state-based surveillance of acute pesticide-related illness and injury. Cincinnati, Ohio: US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health. Available: <http://www.cdc.gov/niosh/pestsrv/> [accessed 13 January 2003].
- CDC. 2003. Surveillance for acute insecticide-related illness associated with mosquito-control efforts—Nine states, 1999–2002. *MMWR* 52:629–634.
- CSTE. 1999. Inclusion of acute pesticide-related illness and injury indicators in the National Public Health Surveillance System (NPHSS). 1999 CSTE Position Statement: Environment 3. Atlanta, Georgia: Council of State and Territorial Epidemiologists. Available: <http://www.cste.org/ps/1999/1999-env-03.htm>
- Das R, Steege A, Baron S, Beckman J, Harrison R. 2001a. Pesticide-related illness among migrant farm workers in the United States. *Int J Occup Environ Health* 7:303–312.
- Das R, Cone J, Sutton P. 2001b. Aircraft disinfection [letter]. *Bull World Health Organ* 79:900–901.
- Dich J, Zahm SH, Hanberg A, Adami HO. 1997. Pesticides and cancer. *Cancer Causes Control* 8:420–443.
- Donaldson D, Kiely T, Grube A. 2002. Pesticides industry sales and usage. 1998 and 1999 market estimates. Washington DC: US Environmental Protection Agency. Report No. EPA-733-R-02-001.
- Eyer P. 1995. Neuropsychopathological changes by organophosphorus compounds—A review. *Hum Exp Toxicol* 14:857–864.
- GAO. 2000. Pesticides. Improvements needed to ensure the safety of farmworkers and their children. Washington DC: United States General Accounting Office. Report No. GAO/RCED-00-40.
- Maddy KT, Edmiston S, Richmond D. 1990. Illness, injuries, and deaths from pesticides exposures in California, 1949–1988. *Rev Environ Contam Toxicol* 114:57–123.
- Mehler LN, O'Malley MA, Krieger RI. 1992. Acute pesticide morbidity and mortality: California. *Rev Environ Contam Toxicol* 129:51–66.
- NEETF. 2002. National Strategies for Health Care Providers: Pesticides initiative. Implementation plan. Washington DC: National Environmental Education & Training Foundation. Available: <http://www.neetf.org/Health/providers/implplan.shtm> [accessed 13 January 2003].
- NIOSH. 2001. Tracking occupational injuries, illnesses, and hazards: The NIOSH surveillance strategic plan. Cincinnati, OH: US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health. DHHS (NIOSH) Publication No. 2001-118.
- Pew Environmental Health Commission. 2001. Strengthening our public health defense against environmental threats: transition report to the new administration. Baltimore, Maryland: Johns Hopkins School of Public Health, Pew Environmental Health Commission. Available: <http://healthyamericans.org/resources/files/transition.pdf> [accessed 13 January 2003].
- Rothman KJ. 1986. *Modern epidemiology*. Boston: Little, Brown. p 164–172.
- Schnitzer PG, Shannon J. 1999. Development of a surveillance program for occupational pesticide poisoning: Lessons learned and future directions. *Public Health Rep* 114:242–248.