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Disclaimer: The findings and conclusions in this report are those of the authors and do not necessarily represent the views of NIOSH or each author's state agency.

Abbreviations:

CDC	Centers for Disease Control and Prevention
CDPR	California Department of Pesticide Regulation
CI	Confidence Interval
CIC	Census Industry Codes
EPA	U.S. Environmental Protection Agency
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
NIOSH	National Institute for Occupational Safety and Health
OR	Odds Ratio
PISP	Pesticide Illness Surveillance Program
SENSOR	Sentinel Event Notification System for Occupational Risks

Abstract

Background: Pesticides are widely used in agriculture and off-target pesticide drift results in exposures to workers and the public. **Objective**: Estimate the incidence of acute illnesses from pesticide drift from outdoor agricultural applications, and describe drift exposure and illness characteristics. **Methods:** Data were obtained from the National Institute for Occupational Safety and Health's Sentinel Event Notification System for Occupational Risks-Pesticides Program and the California Department of Pesticide Regulation. Drift included off-target movement of pesticide spray, volatiles, and contaminated dust. Acute illness cases were characterized by demographics, pesticide and application variables, health effects, and contributing factors. **Results:** During 1998–2006, 2,945 cases associated with agricultural pesticide drift were identified from 11 states. Forty-seven percent had exposures at work, 92% experienced low severity illness, and 14% were children (<15 years). The annual incidence ranged from 1.39 to 5.32 per million persons over the 9-year period. The overall incidence (in million person-years) was 114.3 for agricultural workers, 0.79 for other workers, 1.56 for nonoccupational cases, and 42.2 for residents in 5 agriculture-intensive counties in California. Soil applications with fumigants were responsible for the largest proportion (45%) of cases. Aerial applications accounted for 24% of cases. Common factors contributing to drift cases included weather conditions, improper seal of the fumigation site, and applicator carelessness near non-target areas. **Conclusions:** Agricultural workers and residents in agricultural regions were found to have the highest rate of pesticide poisoning from drift exposure, and soil fumigations were a major hazard causing large drift incidents. These findings highlight areas where interventions to reduce off-target drift could be focused.

Introduction

Pesticide drift, which is the off-target movement of pesticides, is recognized as a major cause of pesticide exposure affecting people as well as wildlife and the environment. In the United States in 2004, more than 1,700 investigations were conducted in 40 states due to drift complaints and 71% of the incidents confirmed that drift arose from pesticide applications to agricultural crops (Association of American Pesticide Control Officials, 2005). Pesticide drift has been reported to account for 37-68% of pesticide illnesses among U.S. agricultural workers (California Department of Pesticide Regulation [CDPR] 2008; Calvert et al. 2008). Community residents, particularly in agricultural areas, are also at risk of exposure to pesticide drift from nearby fields. Agricultural pesticides are often detected in rural homes (Harnly et al. 2009; Quandt et al. 2004). Alarcon et al. (2005) reported that 31% of acute pesticide illnesses that occurred at U.S. schools were attributed to drift exposure.

The occurrence and extent of pesticide drift is affected by many factors such as the nature of the pesticide (e.g., fumigants are highly volatile, increasing their propensity for off-site movement [U.S. Environmental Protection Agency (EPA), 2010]), equipment and application techniques (e.g., size and height of the spray nozzles), the amount of pesticides applied, weather (e.g., wind speed, temperature inversion), and operator care (Hofman and Solseng 2001). Pesticide applicators are required to use necessary preventive measures and comply with label requirements to minimize pesticide drift. Pesticide regulations such as the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and the Worker Protection Standard, an amendment to FIFRA, require safety measures for minimizing the risk of pesticide exposure, and many states have additional regulations for drift mitigation (Feitshans 1999).

Better understanding about the magnitude, trend, and characteristics of pesticide poisoning from drift exposure of agricultural pesticides would assist regulatory authorities with regulatory, enforcement, and education efforts. The purpose of this study was to estimate the magnitude and incidence of acute pesticide poisoning associated with pesticide drift from outdoor agricultural applications in the U.S. during 1998–2006 and describe the exposure and illness characteristics of pesticide poisoning cases arising from off-target drift. Factors associated with illness severity and large events were also examined.

Materials and Methods

Data on acute pesticide poisoning cases were obtained from the National Institute for Occupational Safety and Health (NIOSH)'s Sentinel Event Notification System for Occupational Risks (SENSOR)-Pesticides program and CDPR's Pesticide Illness Surveillance Program (PISP). The SENSOR-Pesticides program has collected pesticide poisoning surveillance data from 12 states, using standardized definitions and variables available since 1998 (Calvert et al. 2010). This study included data from 11 states for the following years: Arizona (1998–2000), California (1998–2006), Florida (1998–2006), Iowa (2006), Louisiana (2000–2006), Michigan (2000–2006), New Mexico (2005–2006), New York (1998–2006), Oregon (1998–2006), Texas (1998–2006), and Washington (2001–2006). North Carolina, which joined SENSOR-Pesticides in 2007, was not included. Because each state removes personal identifiers from the data prior to submission to the Centers for Disease Control and Prevention (CDC), this study was exempt from consideration by the federal Human Subjects Review Board.

Participating surveillance programs identify cases from multiple sources including health care providers, poison control centers, workers' compensation claims, and state or local government agencies. They collect information on the pesticide exposure incident through investigation, interview, and/or medical record review. On some occasions such as large drift events, active surveillance is undertaken for further case finding by interviewing individuals living or working within the vicinity affected by the off-target drift (Barry et al. 2010). Although SENSOR-Pesticides focuses primarily on occupational pesticide poisoning surveillance, all of the SENSOR-Pesticides state programs except California collect data on both occupational and nonoccupational cases. In California, PISP captures both occupational and nonoccupational cases. SENSOR-Pesticides and PISP classify cases based on the strength of evidence for pesticide exposure, health effects, and the known toxicology of the pesticide, and use slightly different criteria for case classification categories (Calvert et al. 2010). This study restricted the analyses to cases classified as *definite*, *probable*, *possible*, or *suspicious* by SENSOR-Pesticides and *definite*, *probable*, or *possible* by PISP. Analyses restricted to *definite* and *probable* cases only were also performed. Because these findings were similar to those that included all four classification categories (i.e., *definite*, *probable*, *possible*, or *suspicious*), only the findings that used the four classification categories were reported.

In this study, a *drift case* was defined as acute health effects in a person exposed to pesticide drift from an outdoor agricultural application. *Drift exposure* included any of the following pesticide exposures outside their intended area of application: 1) spray, mist, fumes, or odor during application; 2) volatilization, odor from a previously treated field, or migration of contaminated dust; and 3) residue left by offsite movement. It should be noted that our drift definition is broader than EPA's "spray or dust drift" definition, which excludes post-application drift caused by erosion, migration, volatility, or windblown soil particles (EPA 2001). A *drift event* was defined as an incident where one or more drift cases experienced drift exposure from a particular source. Both occupational and nonoccupational cases were included. An *occupational case* was defined as an individual exposed while at work. Among occupational cases, *agricultural workers* were identified using 1990 and 2002 Census Industry Codes (CIC): (1990 CIC = 010, 011, 030; 2002 CIC = 0170, 0180, 0290) (U.S. Census Bureau 1992, 2005).

The process of case selection is presented in Figure 1. We selected cases if exposed to pesticides applied for agricultural use including farm, nursery, or animal production, and excluded cases exposed by ingestion, direct spray, spill, or other direct exposure. We then manually reviewed all case reports and excluded persons exposed to pesticides used for indoor applications (e.g., greenhouses, produce packing facilities), persons exposed within a treated area (e.g., pesticide applicators exposed by pesticides blown back by wind, workers working within or passing through the field being treated), and persons exposed to pesticides being mixed, loaded, or transported. Drift cases therefore represented the remaining 9% and 27% of all pesticide illness cases identified by the SENSOR-Pesticides and PISP, respectively. We also searched for duplicates from the two programs identifying California cases. Since personal identifiers were unavailable, date of exposure, age, sex, active ingredients, and county were used for comparison. A total of 60 events and 171 cases were identified by both California programs. These were counted only once and were included in the PISP total only.

Drift events and cases were analyzed by the following variables: state, year and month of exposure, age, gender, location of exposure, health effects, illness severity, pesticide functional/chemical class, active ingredient, target of application, application equipment, detection of violations, and factors contributing to the drift incident. EPA toxicity categories ranging from toxicity I (the most toxic) to IV (the least toxic) were assigned to each product (EPA 2007). Cases exposed to multiple products were assigned to the toxicity category of the most toxic pesticide they were exposed to. Illness severity was categorized into *low, moderate,* and *high* using criteria developed by the SENSOR-Pesticides program (Calvert et al. 2010). *Low* *severity* refers to mild illnesses that generally resolve without treatment. *Moderate severity* refers to illnesses that are usually systemic and require medical treatment. *High severity* refers to life-threatening or serious health effects that may result in permanent impairment or disability. Contributing factors were retrospectively coded with available narrative descriptions. One NIOSH researcher (SJL) initially coded contributing factors for all cases. Next, for SENSOR-Pesticides cases, state health department staff reviewed the codes and edited as necessary. Any discrepancies were resolved by a second NIOSH researcher (GMC). For PISP cases, relatively detailed narrative descriptions were available for all incidents. These narratives summarize investigation reports provided by county agriculture commissioners, who investigate all suspected pesticide poisoning cases reported in their county. After initial coding, two NIOSH researchers discussed those narratives that lacked clarity to reach consensus.

Data Analysis

Data analysis was performed with SAS v 9.1. Descriptive statistics were used to characterize drift events and cases. Incidence rates were calculated by geographic region, year, sex, and age group. The numerator represented the total number of respective cases in 1998–2006. Denominators were generated using the Current Population Survey microdata files for the relevant years (U.S. Census Bureau 2009). For total and nonoccupational rates, the denominators were calculated by summing the annual average population estimates. A nonoccupational rate for agriculture-intensive areas was calculated by selecting the five counties in California where the largest amount of pesticides were applied in 2008 (Fresno, Kern, Madera, Monterey, and Tulare) (CDPR 2010). For occupational rates, the denominators were calculated by summing the annual employment estimates including both “employed at work” and “employed but absent.” The denominator for agricultural workers was obtained using the same 1990/2002 CIC codes used to define agricultural worker cases (U.S. Census Bureau 1992, 2005). Moreover, in California where data on pesticide usage are available, incidence was calculated per number of agricultural applications and amount of pesticide active ingredient applied (CDPR 2009). Incidence trend over time was examined by fitting a Poisson regression model of rate on year and deriving the regression coefficient and its 95% confidence intervals (CIs).

Drift events were dichotomized by the size of events into *small events* involving < 5 cases and *large events* involving ≥ 5 cases. This cut point was based on one of the criteria used by CDPR to prioritize event investigations (CDPR 2001). Illness severity was dichotomized into *low* and *moderate/high*. Simple and multivariable logistic regressions were performed. Odds ratios (OR) and 95% CIs were calculated.

Results

Number and Incidence of Drift Events and Cases

From 1998 through 2006, we identified 643 events and 2,945 illness cases associated with pesticide drift from agricultural applications (Figure 1). Of these, 382 events (59%) and 791 cases (27%) were identified by SENSOR-Pesticides (excluding 60 events and 171 cases also identified by PISP), and 261 events (41%) and 2,154 cases (73%) were identified by PISP. Drift cases consisted of 53 definite (1.8%), 2,019 probable (68.6%), 823 possible (27.9%), and 50 suspicious (1.7%) cases. Among drift cases, 1,565 (53%) were nonoccupational and 1,380 (47%) were occupational. Agricultural workers accounted for 73% (n=1,010) of the occupational cases. A total of 340 events (53%) occurred between May and August and these involved 1,407 cases (48%).

The overall incidence rate of drift-related pesticide poisoning was 2.93/million person-years (Table 1). The rates of nonoccupational and occupational drift-related pesticide poisoning were 1.56 and 2.89, respectively. Among occupational cases, the rate was 114.3 for agricultural workers and 0.79 for all other workers. Among nonoccupational cases identified in California, the rate was 42.2 for residents in the 5 agriculture-intensive counties and 0.61 for residents of all other California counties (data not shown). The rate was highest in the western states for both nonoccupational and occupational cases (Table 1). In California, per 100,000 agricultural applications, 1.6 drift events and 11.8 cases were identified; per 10 million pounds applied, 1.9 events and 14.4 cases were identified (data not shown).

The total annual incidence rate ranged from 1.39 to 5.32 per million persons over the 9-year time period (Table 1). Over time, the rate of drift cases involved in large events showed the same pattern as the rate of all drift cases, showing a spike every three years (Figure 2). The rate of drift cases involved in small events varied within a narrow range from 0.49 to 1.11 and there was no significant rate change over this time period; however, for the 5 states that provided data for all 9 years, a significant decrease in the rate was found (i.e., an estimated 9% decrease per year, 95% CI 3–15%, $p = 0.004$).

Men comprised 53% of all cases (Table 1). The rate by gender was similar among nonoccupational cases. For occupational cases, the rate was 1.25 times higher in male workers than female workers, but 2.89 times higher in female agricultural workers than male agricultural workers. Among nonoccupational cases, children aged < 15 years accounted for 33% of cases with known age and showed the highest rate (1.88/million person-years) (Table 1).

Responsible Pesticides, Application Targets, and Application Equipment

In 430 (67%) of 643 drift events, exposure was to pesticides from a single functional class (Table 2). Insecticides were the most commonly identified (31% of events), accounting for 23% (n=678) of all cases. Fumigants were involved in only 8% of drift events but accounted for

45% (n=1,330) of all cases. Organophosphorous compounds were the most common pesticide chemical class involved in drift events (28%). Most cases (66%) were exposed to toxicity I (high toxicity) pesticides.

For the intended application targets, 71% of events involved applications to fruit, grain/fiber/grass, or vegetable crops (Table 2). Soil applications accounted for 9% of drift events and 45% of all cases. For application equipment, aerial applications (e.g., by airplane) were responsible for 39% of drift events, accounting for 24% of all cases. Chemigation (i.e., application via an irrigation system) or soil injectors were used in 7% of drift events and accounted for 44% of cases. All soil injector events and 95% of chemigation events involved the use of fumigants applied to soil (data not shown).

Location of Exposure and Health Effects

Common exposure locations were private residences (44%) and farms/nurseries (37%) (Table 3). More than half of cases experienced ocular (58%) or neurological (53%) symptoms/signs and illness severity was low for most cases (92%) (Table 3). Moderate/high severity illness was significantly associated with female sex, older age groups, and exposure to multiple active ingredients, before and after controlling for other case and pesticide characteristics ($p < 0.05$) (Table 4). Compared to fumigants, exposures to herbicides, insecticides, or multiple classes were significantly associated with moderate/high severity illness. Table 5 provides the list of 15 active ingredients most commonly found among drift cases and their distribution according to illness severity.

Size of Drift Events

Most drift events involved a single case (n=387, 60%). For multi-person events, 168 events (26% of the total) involved 2–4 cases, 78 events (12%) involved 5–29 cases, and 10 events (1.5%) involved ≥ 30 cases. Table 6 provides details on the 10 largest events. Detailed investigation reports of some of these events are available elsewhere (Barry et al. 2010; CDC 2004; O'Malley et al. 2005). The occurrence of large versus small events (events with ≥5 cases compared with <5 cases) was significantly associated with the use of fumigants (compared to insecticides), and applications to soil, small fruit crops, or leafy vegetable crops (compared to other targets) ($p < 0.05$) (Table 7).

Contributing Factors to Drift Incidents

Of 299 drift events with information on violations of pesticide regulations, 220 (74%) had one or more violations and accounted for 2,093 cases (89% of cases with violation information) (Table 8). However, not all of the observed violations may have directly contributed to the drift exposure. Factors contributing to the drift exposure were identified in 164 events accounting for 1,544 (52%) cases. Common contributing factors identified for drift events included applicators' carelessness near/over non-target sites (e.g., flew over a house, did not turn off a nozzle at the end of the row), unfavorable weather conditions (e.g., high wind speed, temperature inversion), and poor communication between applicators/growers and others. Improper seal of the fumigation site (e.g., tarp tear, early removal of seal), identified in 9 events, accounted for the largest proportion (60%) of cases with contributing factors identified.

The distance between the application and exposure site was identified in 1,428 (48%) cases (Table 8). Occupational cases accounted for 68% of cases exposed within 0.25 miles of the application site, and nonoccupational cases accounted for 73% of cases exposed over 0.25 miles away.

Discussion

To our knowledge, this is the first comprehensive report of drift-related pesticide poisoning in the US. We identified 643 events involving 2,945 illness cases associated with pesticide drift from outdoor agricultural applications during 1998–2006. Pesticide drift included pesticide spray, mist, fume, contaminated dust, volatiles and odor that moved away from the application site during or after the application. While the incidence for cases involved in small drift events (<5 cases) tended to decrease over time, the overall incidence maintained a consistent pattern chiefly driven by large drift events. Large drift events were commonly associated with soil fumigations.

Occupational Exposure

Occupational pesticide poisoning is estimated at 12–21/million U.S. workers per year (Calvert et al. 2004; Council of State and Territorial Epidemiologists n.d.). Compared to those estimates, our estimated incidence of 2.89/million worker-years suggests that 14–24% of occupational pesticide poisoning may be attributed to off-target drift from agricultural applications. It should be noted that our study included pesticide drift from outdoor applications only and excluded workers exposed within the application area. Our findings show that the risk of illness resulting from drift exposure is largely borne by agricultural workers, and the incidence (114.3/million worker-years) was 145 times greater than that for all other workers. Current regulations require agricultural employers to protect workers from exposure to agricultural pesticides, and pesticide product labels instruct applicators to avoid contacting humans directly or through drift (EPA 2009).

Our study found that the incidence of drift-related pesticide poisoning was higher among female and younger agricultural workers and in western states. These groups were previously found to have a higher incidence of pesticide poisoning (Calvert et al. 2008). It is not known why the incidence is higher among female and younger agricultural workers, but hypotheses include that these groups are at greater risk of exposure, that they are more susceptible to pesticide toxicity, or that they are more likely to report exposure/illness or seek medical attention. However, consistent patterns were not observed among workers in other occupations, requiring further research to identify the explanation. The higher incidence in the western states may suggest that workers in this region are at higher risk of drift exposure; however, it may also have resulted from better case identification in California and Washington states through their higher-staffed surveillance programs, extensive utilization of workers' compensation reports in these states, and use of active surveillance for some large drift events in California.

Nonoccupational Exposure

This study found that more than half of drift-related pesticide poisoning cases resulted from nonoccupational exposures and 61% of those were exposed to fumigants. California data suggest that residents in agriculture-intensive regions have a 69 times higher risk of pesticide poisoning from drift exposure compared to other regions. This may reflect California's use of active surveillance for some large drift events. Children were found to have the greatest risk among nonoccupational cases. The reasons are not known but may be because children have higher pesticide exposures, greater susceptibility to pesticide toxicity or greater medical attention seeking by concerned parents. Recently several organizations submitted a petition to the U.S. EPA asking the agency to evaluate children's exposure to pesticide drift and adopt interim prohibitions on the use of drift-prone pesticides near homes, schools, and parks (Goldman et al. 2009).

Contributing Factors

Soil fumigation was a major cause of large drift events, accounting for the largest proportion of cases. Due to the high volatility of fumigants, specific measures are required to prevent emissions after completion of the application. Given the unique drift risks posed by fumigants, EPA regulates the drift of fumigants separately from non-fumigant pesticides. EPA recently adopted new safety requirements for soil fumigants which took effect in early 2011, and include comprehensive measures designed to reduce the potential for direct fumigant exposures, reduce fumigant emissions, improve planning, training, and communications, and promote early detection and appropriate responses to possible future incidents (EPA 2010). Requirements for buffer zones are also strengthened. For example, fumigants that generally require a > 300 foot buffer zone are prohibited within 0.25 miles (1,320 feet) of "difficult-to-evacuate" sites (e.g., schools, daycare centers, hospitals). We found that, of 738 fumigant-related cases with information on distance, 606 (82%) occurred > 0.25 miles from the application site, which suggests that the new buffer zone requirements, independent of other measures to increase safety, may not be sufficient to prevent drift exposure.

This study also showed the need to reinforce compliance with weather-related requirements and drift monitoring activities. Moreover, applicators should be alert and careful, especially when close to non-target areas such as adjacent fields, houses, and roads. Applicator carelessness contributed to 79 events (48% of 164 events where contributing factors were identified), of which 56 events involved aerial applicators. Aerial application was the most frequent application method found in drift events, accounting for 249 events (39%). Drift hazards from aerial applications have been well documented (CDC 2008; Weppner et al. 2006). Applicators should use all available drift management measures and equipment to reduce drift exposure, including new validated drift reduction technologies as they become available.

Limitations

This study requires cautious interpretation especially for variables with missing data on many cases (e.g., age, violation, contributing factors, distance). This study also has several limitations. First, our findings likely underestimate the actual magnitude of drift events and cases because case identification principally relies on passive surveillance systems. Such under-reporting might have allowed the totals to be appreciably influenced by a handful of California episodes in which active case-finding located relatively large numbers of affected people. Pesticide-related illnesses are underreported due to individuals not seeking medical attention (because of limited access to health care or mild illness), misdiagnosis, and health care provider failure to report cases to public health authorities (Calvert et al. 2008). Data from the National Agricultural Workers Survey suggests that the pesticide poisoning rates for agricultural workers may be an order of magnitude higher than those identified by the SENSOR-Pesticides and PISP programs (Calvert et al. 2008). Second, the incidence of drift cases from agricultural applications may have been underestimated by using crude denominators of total population and employment estimates which may also include those who are not at risk. On the other hand, the incidence for agricultural workers may have been overestimated if the denominator data undercounted undocumented workers. Third, the data may include false-positive cases because clinical findings of pesticide poisoning are nonspecific and diagnostic tests are not available or rarely performed. Fourth, when data from SENSOR-Pesticides and PISP were combined, some duplication of cases and misclassification of variables may have occurred although steps were taken to identify and resolve discrepancies. Also there may be differences in case detection sensitivity between SENSOR-Pesticides and PISP since the two programs use slightly different case definitions. Lastly, contributing factor information was not available for 48% of cases, either because an in-depth investigation did not occur, or sufficiently detailed findings were not entered into the database. The retrospective coding of contributing factors was often based on limited data and may have produced some misclassification.

Conclusion

The study findings suggest that the incidence of acute illness from off-target pesticide drift exposure was relatively low during 1998–2006 and most cases presented with low-severity illness. However, the rate of poisoning from pesticide drift was 69 times higher for residents in 5 agriculture-intensive California counties compared with other counties, and the rate of occupationally exposed cases was145 times greater in agricultural workers than in non-agricultural workers. These poisonings may largely be preventable through proper prevention measures and compliance with pesticide regulations. Aerial applications were the most frequent method associated with drift events, and soil fumigations were a major cause of large drift events. These findings highlight areas where interventions to reduce pesticide drift could be focused.

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Table 1. Number and incidence rate[a] of off-target drift events and pesticide poisoning cases by year, region, sex, and age, 11 States, 1998-2006

	Drift Events		Drift Cases												
			All Cases			Nonoccupational Cases		Occupational Cases						
								Ag Worker Cases[d]			Other Worker Cases			Total
Variable	Count	%	Count	Population estimate[b]	Rate	Count	Rate[c]	Count	Employment estimate[b,d]	Rate	Count	Employment estimate[b]	Rate	Rate
Total	643	100	2,945	1004.1	2.93	1,565	1.56	1,010	8.83	114.33	370	468.0	0.79	2.89
Year of exposure (# of states included)														
1998 (6)	60	9.3	130	93.6	1.39	46	0.49	45	1.11	40.46	39	43.2	0.90	1.90
1999 (6)	82	12.8	407	95.0	4.28	273	2.87	72	1.12	64.22	62	44.1	1.41	2.97
2000 (8)	64	10.0	193	110.3	1.75	76	0.69	93	1.24	74.94	24	51.8	0.46	2.21
2001 (8)	88	13.7	177	112.6	1.57	98	0.87	43	1.12	38.47	36	52.5	0.69	1.47
2002 (8)	81	12.6	580	113.7	5.10	271	2.38	281	1.11	252.33	28	52.2	0.54	5.80
2003 (8)	75	11.7	348	116.4	2.99	265	2.28	43	0.79	54.64	40	53.7	0.74	1.52
2004 (8)	47	7.3	232	117.4	1.98	43	0.37	177	0.75	235.33	12	54.7	0.22	3.41
2005 (9)	70	10.9	642	120.6	5.32	409	3.39	168	0.75	224.77	65	56.8	1.14	4.05
2006 (10)	76	11.8	236	124.5	1.90	84	0.67	88	0.84	104.53	64	59.1	1.08	2.54
Region														
West[e]	433	67.3	2,484	397.9	6.24	1,240	3.12	933	4.44	210.20	311	184.9	1.68	6.57
South[f]	193	30.0	426	365.6	1.17	311	0.85	59	3.25	18.17	56	170.7	0.33	0.66
East/Central[g]	17	2.6	35	240.6	0.15	14	0.06	18	1.15	15.68	3	112.5	0.03	0.18
Sex	n/a											0.0		
Male			1560	491.6	3.17	742	1.51	554	6.90	80.27	264	251.6	1.05	3.16
Female			1360	512.5	2.65	807	1.57	448	1.93	231.90	105	216.5	0.49	2.53
Unknown			25	--	--	16	--	8	--	--	1	--	--	--
Age	n/a													
< 15			418	221.2	1.89	415	1.88	3	--	--	0	--	--	--
15–24			398	142.0	2.80	182	1.28	182	1.44	126.39	34	67.8	0.50	3.12
25–34			453	140.0	3.24	140	1.00	240	1.81	132.53	73	106.8	0.68	2.88
35–44			458	156.7	2.92	181	1.16	187	2.08	89.89	90	122.3	0.74	2.23
45–54			306	136.1	2.25	172	1.26	78	1.59	49.00	56	104.6	0.54	1.26
55–64			164	90.9	1.80	103	1.13	37	1.10	33.61	24	52.0	0.46	1.15
65+			92	117.2	0.78	80	0.68	9	0.81	11.11	3	14.6	0.21	0.78
Unknown			656	--	--	292	--	274	--	--	90	--	--	--

a. Per 1,000,000 persons.
b. Numbers (in million) were estimated using the Current Population Survey data. Participating years vary by state. Only years of participation were included.
c. Denominators were population estimates.
d. Cases and employment estimates of agricultural workers were defined with 1990/2002 Census Industry Codes (010, 011, 030; 0170, 0180, 0290).
e. Arizona, California, New Mexico, Oregon, Washington
f. Florida, Louisiana, Texas
g. Iowa, Michigan, New York

Table 2. Off-target drift events and pesticide poisoning cases by pesticide and application characteristics, 11 states, 1998-2006

Variable	Drift Events (n=643) N	Drift Events (n=643) %	Drift Cases: Total (n=2,945) N	Drift Cases: Total (n=2,945) %	Drift Cases: Occupational (n=1,380) %	Drift Cases: Nonoccupational (n=1,565) %
Pesticide functional class						
Insecticide only	198	30.8	678	23.0	32.9	14.3
Herbicide only	108	16.8	195	6.6	4.0	8.9
Fungicide only	29	4.5	64	2.2	3.7	0.8
Fumigant only	52	8.1	1,330	45.2	27.0	61.2
Other, single	43	6.7	87	3.0	2.8	3.1
Multiple	207	32.2	585	19.9	29.4	11.4
Unknown	6	0.9	6	0.2	0.2	0.2
Common pesticide chemical class[a]						
Organophosphorous compound	181	28.1	660	22.4	36.7	9.8
Inorganic compound	87	13.5	231	7.8	11.1	5.0
Pyrethroid	52	8.1	207	7.0	9.6	4.7
Dithiocarbamates[b]	47	7.3	726	24.7	22.5	26.5
N-methyl carbamates	33	5.1	71	2.4	4.1	1.0
Chlorophenoxy compound	26	4.0	47	1.6	0.9	2.2
Triazines	11	1.7	34	1.2	1.1	1.2
Maximum toxicity category						
I	203	31.6	1,944	66.0	59.9	71.4
II	167	26.0	468	15.9	21.2	11.2
III	154	24.0	327	11.1	13.6	8.9
Unknown	119	18.5	206	7.0	5.2	8.6
Application target						
Fruit crops	189	29.4	588	20.0	27.6	13.2
Grain/fiber/grass crops	185	28.8	411	14.0	12.8	15.0
Vegetable crops	85	13.2	374	12.7	22.9	3.7
Soil	55	8.6	1,337	45.4	27.5	61.2
Landscape/forest	32	5.0	64	2.2	2.8	1.7
Undesired plants	29	4.5	44	1.5	0.9	2.0
Other (e.g., misc. crops, seed, livestock farm)	27	4.2	66	2.2	2.0	2.5
Unknown	41	6.4	61	2.1	3.6	0.8
Application equipment						
Aerial applicator	249	38.7	695	23.6	32.0	16.2
Handheld or backpack sprayer	24	3.7	63	2.1	3.8	0.6
Chemigation	22	3.4	752	25.5	16.4	33.5
Soil injector	20	3.1	558	18.9	10.0	26.8
Other ground applicator	254	39.5	747	25.4	32.6	19.0
Multiple	8	1.2	41	1.4	0.2	2.4
Unknown	66	10.3	89	3.0	4.9	1.4

a. Categories with the largest numbers of cases. Events/Cases can be exposed to multiple categories.
b. Mostly from single products.

Table 3. Location of exposure, health effects, and illness severity of drift cases (n=2,945)

Variable	%
Location of exposure	
Private residence	44.5
Farm/Nursery	36.7
Road/Right-of-way	5.6
School	3.6
Agricultural processing facility	2.4
Other/Unknown	7.2
Health effect[a]	
Eye (e.g., pain/irritation/inflammation, lacrimation)	58.2
Neurological (e.g., headache, paresthesia, dizziness)	52.8
Respiratory (e.g., dyspnea, respiratory tract pain/irritation, cough)	47.8
Gastrointestinal (e.g., vomiting, nausea, diarrhea, abdominal pain)	41.5
Skin (e.g., pruritus, pain/irritation, rash)	14.7
Cardiovascular (e.g., chest pain)	5.1
Other (e.g., fatigue, fever)	11.4
Illness severity	
Low	92.2
Moderate	7.3
High	0.5

a. Cases can be included in multiple categories.

Table 4. Illness severity by case and pesticide characteristics

Variable	High/Moderate Severity (n=230) N	%	Low severity (n=2,715) N	%	High/Moderate severity (versus Low) OR	95% CI	aOR[b]	95% CI
Sex[a]								
Female	126	54.8	1,234	45.5	1.43	(1.09,1.87)	1.53	(1.15,2.04)
Male	104	45.2	1,456	53.6	Ref		Ref	
Age								
< 15	16	7.0	402	14.8	Ref		Ref	
15-24	28	12.2	370	13.6	1.90	(1.01,3.57)	1.34	(0.68,2.62)
25-34	48	20.9	405	14.9	2.98	(1.66,5.33)	1.95	(1.02,3.71)
35-44	48	20.9	410	15.1	2.94	(1.64,5.27)	1.91	(1.02,3.58)
45-54	38	16.5	268	9.9	3.56	(1.95,6.52)	2.34	(1.24,4.41)
55-64	21	9.1	143	5.3	3.69	(1.87,7.27)	2.42	(1.20,4.91)
65+	16	7.0	76	2.8	5.29	(2.54,11.03)	3.67	(1.72,7.86)
Unknown	15	6.5	641	23.6	0.59	(0.29,1.20)	0.63	(0.30,1.33)
Work-related								
Yes	126	54.8	1,254	46.2	1.41	(1.08,1.85)	0.99	(0.70,1.40)
No/Unknown	104	45.2	1,461	53.8	Ref		Ref	
No. of active ingredients								
One	90	39.1	1,719	63.3	Ref		Ref	
More than one	140	60.9	996	36.7	2.72	(2.07,3.58)	1.42	(1.02,1.99)
Pesticide functional class								
Fumigant	35	15.2	1,295	47.7	Ref		Ref	
Herbicides	33	14.3	162	6.0	7.54	(4.56,12.46)	4.10	(2.34,7.19)
Insecticide	79	34.3	599	22.1	4.88	(3.24,7.35)	3.34	(2.10,5.32)
Fungicides	2	0.9	62	2.3	1.19	(0.28,5.08)	0.77	(0.18,3.37)
Multiple	71	30.9	514	18.9	5.11	(3.37,7.76)	3.09	(1.85,5.16)
Other/Unknown	10	4.3	83	3.1	4.46	(2.13,9.32)	2.82	(1.29,6.15)

a. Excluded unknown cases.
b. Adjusted for all other variables.

Table 5. Fifteen most common active ingredients for drift cases and percentage of high/moderate severity

Active ingredient	Functional class	Chemical class	Cases[a] (N=2,945)	Cases exposed to single active ingredient: Total (n=1,809)	Cases exposed to single active ingredient: % of High/Moderate Severity (n=90)[b]
Metam-sodium	Fumigant	Dithicarbamate	664	664	3
Chloropicrin	Fumigant	Trichloronitromethane	637	532	1
Chlorpyrifos	Insecticide	Organophosphate	240	49	10
Sulfur	Insecticide/Fungicide	Inorganic compound	147	32	25
Mancozeb	Fungicide	Dithicarbamate	144	4	0
Methamidophos	Insecticide	Organophosphate	133	0	0
Malathion	Insecticide	Organophosphate	122	96	11
Spinosad	Insecticide	Spinosyn	107	1	0
Methyl-bromide	Fumigant	Alkyl bromide	84	11	27
Dimethoate	Insecticide	Organophosphate	68	10	20
Cyfluthrin	Insecticide	Pyrethroid	59	2	0
Methomyl	Insecticide	N-methyl carbamate	56	13	15
Atrazine	Herbicide	Triazine	54	8	0
lambda-Cyhalothrin	Insecticide	Pyrethroid	52	39	3
Propargite	Acaricide/miticide	Sulfite ester	52	10	30

a. Can be exposed to other active ingredients also.
b. High (n=7), Moderate (n=83)

Table 6. 10 largest drift events, 1998-2006

State	Year	Cases			Pesticide application		
		Total (n=1,293)	Occupational (n=452)	Non-occupational (n=841)	Target	Equipment	Active ingredient
California	1999	170	6	164	Soil	Chemigation	Metam-sodium
California	2000	33	33	0	Almonds	Aerial application	Chlorpyrifos, propargite
California	2002	250	72	178	Soil	Soil injector	Metam-sodium
California	2002	123	123	0	Soil	Chemigation	Metam-sodium
California	2003	161	10	151	Soil	Soil injector	Chloropicrin
California	2004	122	122	0	Potatoes	Aerial application	Methamidophos
California	2005	324	1	323	Soil	Chemigation	Chloropicrin
California	2005	42	42	0	Soil	Chemigation	Metam-sodium
California	2005	34	34	0	Oranges	Ground sprayer	Cyfluthrin, spinosad
Texas	2005	34	9	25	Cotton	Ground sprayer	Lambda-cyhalothrin

Table 7. Factors associated with large drift events (≥5 cases)

	Small Event (n=555)		Large Event (n=88)		Large Event (versus Small)	
	N	%	N	%	OR	(95% CI)
Pesticide functional class						
Insecticide	172	31.0	26	29.5	Ref	
Fumigant	29	5.2	23	26.1	5.25	(2.64,10.41)
Multiple combination	178	32.1	29	33.0	1.08	(0.61,1.91)
Other single pesticide class or unknown	176	31.7	10	11.4	0.38	(0.18,0.80)
Application target						
Soil	31	5.6	24	27.3	8.50	(4.57,15.79)
Small fruit crops[a]	38	6.8	14	15.9	4.04	(2.03,8.06)
Leafy vegetable crops[b]	25	4.5	8	9.1	3.51	(1.49,8.27)
Other[c]	461	83.1	42	47.7	Ref	
Application method						
Aerial application	223	40.2	26	29.5	0.91	(0.54,1.53)
Chemigation	20	3.6	22	25.0	8.58	(4.31,17.09)
Other[d]	312	56.2	40	45.5	Ref	

a. e.g., berries, grapes, currant.
b. e.g., beets, celery, broccoli, lettuce, spinach
c. Includes tall fruit or other vegetable crops, other crop categories, landscape/forest, undesired plants, livestock farms, unknown.
d. Includes other ground application equipment, multiple, and unknown.

Table 8. Violation in and contributing factors to occurrence of drift incidents/exposures

	Drift Events (n=643)		Drift Cases			
			Occupational (n=1,380)		Nonoccupational (n=1,565)	
Variable	N	%	N	%	N	%
Violation of federal/state pesticide regulation						
Yes	220[a]	73.6	971	85.6	1122	93.2
No	79	26.4	164	14.4	82	6.8
Unknown/Pending	344		245		361	
At least one contributing factor identified[b]	164	(100)	486	(100)	1,058	(100)
Applicator carelessness near non-target sites[c]	79	(48.2)	49	(10.1)	98	(9.3)
By aerial applicator	56	(34.1)	21	(4.3)	66	(6.2)
Weather (wind, temperature inversion)	75	(45.7)	309	(63.6)	593	(56.0)
Poor/ineffective communication	19	(11.6)	102	(21.0)	11	(1.0)
Improper seal of fumigation site[d]	9	(5.5)	94	(19.3)	837	(79.1)
Inappropriate monitoring[e]	7	(4.3)	118	(24.3)	199	(18.8)
Applicator not properly trained or supervised	5	(3.0)	45	(9.3)	0	(0.0)
Excessive application	4	(2.4)	20	(4.1)	6	(0.6)
Use of inadequate equipment[f]	2	(1.2)	125	(25.7)	2	(0.2)
Other[g]	8	(4.9)	28	(5.8)	206	(19.5)
Distance from application site	n/a		700	(100)	728	(100)
≤ 50 feet			66	(9.4)	54	(7.4)
> 50–100 feet			77	(11.0)	29	(4.0)
> 100–300 feet			113	(16.1)	69	(9.5)
> 300 feet–0.25 mile			267	(38.1)	93	(12.8)
> 0.25–0.5 mile			175	(25.0)	256	(35.2)
> 0.5–1 mile[h]			0	(0.0)	116	(15.9)
> 1 mile[i]			2	(0.3)	111	(15.2)

Note: Percentages in parentheses were calculated only among cases with available data
a. 159 (72%) were identified by the California Department of Pesticide Regulation
b. Cases can be included in multiple categories.
c. e.g., the applicator didn't turn off a nozzle at the end of the row, the crop duster flew overhead.
d. e.g., leakage from torn tarp, early removal of seal, use of contaminated water
e. e.g., did not measure wind speed, did not monitor drift from the application site
f. e.g., used longer spray boom than specified on the label, used sprinklers without required calibration device.
g. e.g., treated additional rows without permission, permeable soil type, aerial application with very low height, building/vehicle ventilator system sucking outside air in
h. Cases are from three events in California, Louisiana, and Washington.
i. Cases are from two events in California.

Figure 1. Eligible pesticide drift events and cases, 11 States, 1998-2006

Figure 2. Incidence rate of pesticide poisoning associated with off-target drift exposure over time, 11 states, 1998-2006

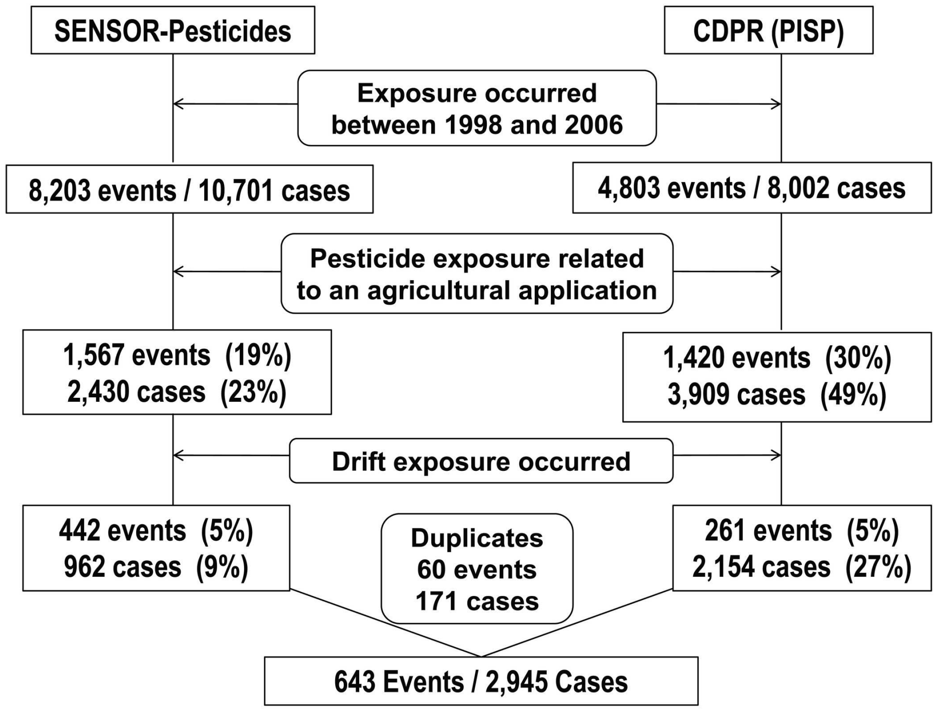

Figure 1. Eligible pesticide drift events and cases, 11 States, 1998-2006
190x142mm (300 x 300 DPI)

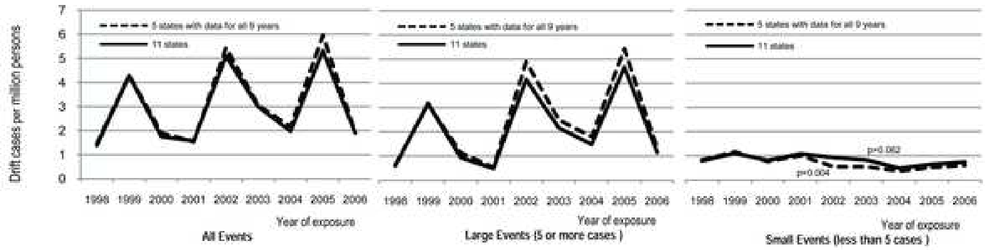

Figure 2. Incidence rate of pesticide poisoning associated with off-target drift exposure over time, 11 states, 1998-2006
50x13mm (300 x 300 DPI)