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Acute Pesticide Illnesses Associated with Off-Target Pesticide Drift from Agricultural Applications: 11 States, 1998–2006

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BACKGROUND: Pesticides are widely used in agriculture, and off-target pesticide drift exposes workers and the public to harmful chemicals.

OBJECTIVE: We estimated the incidence of acute illnesses from pesticide drift from outdoor agricultural applications and characterized drift exposure and illnesses.

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: From 1998 through 2006, we identified 2,945 cases associated with agricultural pesticide drift from 11 states. Our findings indicate that 47% were exposed 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 five agricultural-intensive counties in California. Soil applications with fumigants were responsible for the largest percentage (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 nontarget areas.

CONCLUSIONS: Agricultural workers and residents in agricultural regions had the highest rate of pesticide poisoning from drift exposure, and soil fumigations were a major hazard, causing large drift incidents. Our findings highlight areas where interventions to reduce off-target drift could be focused.

KEY WORDS: agriculture, drift, pesticides, poisoning, surveillance. Environ Health Perspect 119:1162–1169 (2011), doi:10.1289/ehp.1002843 [Online 6 June 2011]
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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 (CICs): 1990 CICs, 010, 011, 030; 2002 CICs, 0170, 0180, 0290 (U.S. Census Bureau 1992, 2005).

Figure 1 presents the process of case selection. 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 released, 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. Because 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 only in the PISP total.

Drift events and cases were analyzed by the following variables: state, year, and month of exposure, age, sex, location of exposure, health effects, illness severity, pesticide functional and chemical class, active ingredient, target of application, application equipment, detection of violations, and factors contributing to the drift incident. U.S. EPA toxicity categories ranging from toxicity I (the most toxic) to IV (the least toxic) were assigned to each product (U.S. 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 (S.J.L.) initially coded contributing factors for all cases. Next, for SENSOR-Pesticides cases, state health department staff reviewed the codes and edited them as necessary. Any discrepancies were resolved by a second NIOSH researcher (G.M.C.). 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, the two

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 person identifiers from the data before 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 medical record review. In California, 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 the SENSOR-Pesticides program 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 toxicity 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. We also performed analyses restricted to definite and probable cases only. Because the findings from these restricted analyses 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 are reported here.

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: a) spray, mist, fumes, or odor during application; b) volatilization, odor from a previously treated field, or migration of contaminated dust; and c) residue left by offsite movement. Our drift definition is broader than U.S. EPA’s “spray or dust drift” definition, which excludes post-application drift caused by erosion, migration, volatility, or windblown soil particles (U.S. EPA 2001). A drift event was defined as an incident where one or more drift cases experienced drift exposure from a particular source.

Figure 1. Eligible pesticide drift events and cases, 11 states, 1998–2006.
NIOSH researchers discussed those narratives that lacked clarity to reach consensus.

Data analysis. Data analysis was performed with SAS software (version 9.1; SAS Institute Inc., Cary, NC). 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 amounts 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 and 2002 CICs used to define agricultural worker cases (U.S. Census Bureau 1992, 2005). Moreover, in California, where data on pesticide use 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 interval (CI).

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 the CDPR to prioritize event investigations.

Table 1. Number and incidence ratea of off-target drift events and pesticide poisoning cases by year, region, sex, and age, 11 states, 1998–2006.

| Variable                  | Drift events | All cases | Nonoccupational cases | Occupational cases | Other worker cases | Agricultural worker cases | Total |
|---------------------------|-------------|-----------|-----------------------|--------------------|-------------------|--------------------------|-------|
|                           | Count (%)   | Count     | Population estimateb | Rate               | Count             | Rate                     | Count |
| Total                     | 643 (100)   | 2,945     | 1,004.1               | 2.93               | 1,565             | 1.56                     | 1,010 |
| Year of exposure (no. states included) |            |           |                       |                    |                   |                          |       |
| 1998 (6)                  | 60 (9.3)    | 130       | 93.6                  | 1.39               | 46                 | 0.49                     | 45    |
| 1999 (6)                  | 82 (12.8)   | 407       | 95.0                  | 4.28               | 273                | 2.87                     | 72    |
| 2000 (8)                  | 64 (10.0)   | 193       | 110.3                 | 1.75               | 76                 | 0.69                     | 93    |
| 2001 (8)                  | 88 (13.7)   | 177       | 112.6                 | 1.57               | 98                 | 0.87                     | 43    |
| 2002 (8)                  | 81 (12.6)   | 580       | 113.7                 | 5.10               | 271                | 2.38                     | 281   |
| 2003 (8)                  | 75 (11.7)   | 348       | 116.4                 | 2.99               | 265                | 2.28                     | 43    |
| 2004 (8)                  | 47 (7.3)    | 232       | 117.4                 | 1.98               | 43                 | 0.37                     | 177   |
| 2005 (9)                  | 70 (10.9)   | 642       | 120.6                 | 5.32               | 409                | 3.39                     | 168   |
| 2006 (10)                 | 76 (11.8)   | 236       | 124.5                 | 1.90               | 84                 | 0.67                     | 88    |
| Region                    |             |           |                       |                    |                   |                          |       |
| Westa                     | 433 (67.3)  | 2,484     | 397.9                 | 6.24               | 1,240              | 3.12                     | 933   |
| Southf                    | 193 (30.0)  | 426       | 365.6                 | 1.17               | 311                | 0.85                     | 59    |
| East/centralg             | 17 (2.6)    | 35        | 240.6                 | 0.15               | 14                 | 0.06                     | 18    |
| Sex                       |             |           |                       |                    |                   |                          |       |
| Male                      | 1,560       | 491.6     | 3.17                  | 742                | 1.51               | 554                       | 64.0  |
| Female                    | 1,360       | 512.5     | 2.65                  | 807                | 1.57               | 448                       | 1.93  |
| Unknown                   | 25          | —         | 16                    | —                  | 8                  | —                        | 1     |
| Age (years)               |             |           |                       |                    |                   |                          |       |
| < 15                      | 418         | 221.2     | 1.89                  | 415                | 1.88               | 3                         | —     |
| 15–24                     | 398         | 142.0     | 2.80                  | 182                | 1.28               | 162                       | 1.44  |
| 25–34                     | 453         | 140.0     | 3.24                  | 140                | 1.00               | 240                       | 1.81  |
| 35–44                     | 458         | 156.7     | 2.92                  | 181                | 1.16               | 167                       | 2.08  |
| 45–54                     | 306         | 136.1     | 2.25                  | 172                | 1.26               | 78                        | 1.59  |
| 55–64                     | 164         | 90.9      | 1.80                  | 103                | 1.13               | 37                        | 1.10  |
| ≥ 65                      | 92          | 117.2     | 0.78                  | 80                 | 0.68               | 9                         | 0.81  |
| Unknown                   | 656         | —         | 292                   | —                  | 274                | —                         | 90    |

Abbreviations: —, the denominator was not available and thus a rate was not calculated, NA, for sex and age, counting the number of events was not applicable.

aPer 1,000,000 persons.
bCases and employment estimates of agricultural workers were defined with 1990 and 2002 CICs (010, 011, 030 and 0170, 0180, 0290, respectively).
cNumbers (in millions) were estimated using the Current Population Survey data (U.S. Census Bureau 2009). Participating years vary by state; only years of participation were included.
dDenominators were population estimates.
eArizona, California, New Mexico, Oregon, Washington.
fFlorida, Louisiana, Texas.
gMowo, Michigan, New York.

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

(CDPR 2001). Illness severity was dichotomized as low and moderate/high. Simple and multivariable logistic regressions were performed. Odds ratios (ORs) 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 per million person-years (Table 1). The rates of nonoccupational and occupational drift-related pesticide poisoning were 1.56 and 2.89 per million persons-years, 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 five 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 persons-years, respectively. Among occupational cases, the rate was 114.3 for agricultural workers. Among nonoccupational cases, children <15 years of age 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 (Class 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. Organophosphorus 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 or signs, and illness severity was low for most cases (92%; Table 3). Moderate/high severity illness was significantly associated with females, older age groups, and exposure to multiple active ingredients, before and after 2003.

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

| Variable                  | Drift events (n = 643) | Total (n = 2,945) | Drift cases |
|---------------------------|------------------------|-------------------|-------------|
|                           | n (%)                  | Occupational n = 1,380 (%) | 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)          | 2.7         | 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 classa |                  |                   |             |
| Organophosphorus 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  |
| Dithiocarbamatesb         | 47 (7.3)               | 725 (24.7)        | 22.5        | 26.5 |
| A/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 (66.6)      | 59.9        | 71.4 |
| II                        | 167 (26.0)             | 468 (15.9)        | 21.2        | 11.2 |
| III                       | 154 (24.0)             | 327 (11.1)        | 13.6        | 8.5  |
| 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., miscellaneous crops, sand, 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 (24.5)        | 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  |

Categories with the largest numbers of cases. Events and cases can be exposed to multiple categories. a Mostly from single products.
controlling for other case and pesticide characteristics (p < 0.05; Table 4). Compared with fumigants, exposures to herbicides, insecticides, or multiple classes were significantly associated with moderate/high illness. Table 5 lists 15 active ingredients most commonly associated with moderate/high illness. 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 (with ≥ 5 vs. < 5 cases) was significantly associated with the use of fumigants (compared with insecticides) and applications to soil, small fruit crops, or leafy vegetable crops (compared with 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 or over nontarget 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 or growers and others. Improper seal of the fumigation site (e.g., tarp tear, early removal of seal), which were identified in nine 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 > 0.25 miles away.

**Discussion**

To our knowledge, this is the first comprehensive report of drift-related pesticide poisoning in the United States. 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. Although 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.

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

| Variable | Percent |
|----------|---------|
| Location of exposure |         |
| Private residence | 44.5 |
| Farm/nursery | 36.7 |
| Road/road-of-way | 5.6 |
| School | 3.6 |
| Agricultural processing facility | 2.4 |
| Other/unknown | 7.2 |
| Health effect* |         |
| Eye (e.g., pain/irritation/inflammation, lacrimation) | 50.8 |
| Neurological (e.g., headache, paresthesia, dizziness) | 92.8 |
| 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 |

*Cases may have been included in multiple categories.

### Table 4. Illness severity by case and pesticide characteristics.

| Variable | Moderate/high severity (n = 230) | Low severity (n = 2,715) | Moderate/high vs. low (OR: 95% CI) | Adjusted OR* (95% CI) |
|----------|-------------------------------|-------------------------|-----------------------------------|----------------------|
| Sex*     |                               |                         |                                   |                      |
| 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 (54.5)            | Reference                         | Reference            |
| Age (years) |                   |                         |                                   |                      |
| < 15     | 16 (7.0)                      | 402 (14.8)              | Reference                         | Reference            |
| 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)            | Reference                         | Reference            |
| No. active ingredients |                   |                         |                                   |                      |
| 1        | 90 (39.1)                     | 1,719 (63.3)            | Reference                         | Reference            |
| > 1      | 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)            | Reference                         | Reference            |
| Herbicides | 33 (14.3)                    | 162 (6.0)               | 7.54 (4.56–12.46)                 | 4.10 (2.34–7.19)     |
| Insecticide | 79 (34.3)                    | 598 (22.1)              | 4.88 (2.24–7.35)                  | 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)     |

*Adjusted for all other variables. *Excluded unknown cases.
product labels instruct applicators to avoid allowing contact with humans directly or through drift (U.S. 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 and illness or seek medical attention. However, we did not observe consistent patterns among workers in other occupations. This finding requires 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 use 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 that 61% of these nonoccupational cases 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 with other regions. This may reflect California’s use of active surveillance for some large drift events. Children had the greatest risk among nonoccupational cases. The reasons for this are not known but may be because children have higher pesticide exposures, greater susceptibility to pesticide toxicity, or because concerned parents are more likely to seek medical attention. 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. Because of 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, U.S. EPA regulates the drift of fumigants separately from nonfumigant pesticides. The U.S. 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 (U.S. 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 the 738 fumigant-related cases with information on

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

| Active ingredient | Functional class | Chemical class   | Casesa (n=2,945) | Total (n=1,809) | Percent moderate/high severity (n=90) |
|-------------------|-----------------|------------------|-----------------|-----------------|-------------------------------------|
| Metam-sodium      | Fumigant        | Dithiocarbamate  | 664             | 664             | 3                                   |
| Chloropirin       | Fumigant        | Trichloronitromethane | 637           | 532             | 1                                   |
| Chlorpyrifos      | Insecticide     | Organophosphate  | 240             | 49              | 10                                  |
| Sulfur            | Insecticide/fungicide | Inorganic compound | 147           | 32              | 25                                  |
| Mancozeb          | Fungicide       | Dithiocarbamate  | 144             | 4               | 0                                   |
| Methamidophos     | Insecticide     | Organophosphate  | 133             | 0               | 0                                   |
| Malathion         | Insecticide     | Organophosphate  | 122             | 96              | 11                                  |
| Spinosad          | Insecticide     | Spinosad         | 107             | 1               | 0                                   |
| Methyl bromide    | Fumigant        | Allyl 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                                   |
| λ-Cyhalothrin     | Insecticide     | Pyrethroid       | 52              | 39              | 3                                   |
| Propargite        | Acradinic/inditico | Sulfite ester   | 52              | 10              | 30                                  |

*Can be exposed to other active ingredients also. High, n = 7; moderate, n = 83.

### Table 6. Ten largest drift events, 1998–2006.

| State          | Year | Total (n=1,293) | Occupational (n=452) | Nonoccupational (n=841) | Target | Equipment | Active ingredient |
|----------------|------|-----------------|----------------------|-------------------------|--------|-----------|-------------------|
| California     | 1999 | 170             | 6                    | 164                     | Soil   | Chemigation | Metam-sodium      |
| California     | 2000 | 33              | 33                   | 0                       | Soil   | Aerial application | Chlorpyrifos       |
| 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 | λ-Cyhalothrin     |

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

| Factor | Small event (n = 555) | Large event (n = 88) | Large event (vs. small), OR (95% CI) |
|--------|-----------------------|----------------------|--------------------------------------|
| Pesticide functional class | Insecticide | 172 (31.0) | 26 (29.5) | Reference |
|        | 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 | 38 (6.8) | 14 (15.9) | 4.04 (2.03–8.06) |
|        | Leafy vegetable crops | 25 (4.5) | 8 (9.1) | 3.51 (1.49–8.27) |
|        | Other | 461 (83.1) | 42 (47.7) | Reference |
| Application method | Aerial application | 223 (40.2) | 26 (29.5) | 0.91 (0.54–1.53) |
|        | Chemigation | 20 (3.6) | 22 (25.0) | 8.38 (4.31–17.09) |
|        | Other | 312 (56.2) | 40 (45.5) | Reference |

*For example, berries, grapes, currants. For example, beets, celery, broccoli, lettuce, spinach. Includes tree fruit or other vegetable crops, other crop categories, landscape and forest, undesired plants, livestock farms, unknown. Includes other ground application equipment, multiple, and unknown.
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 shows the need to reinforce compliance with weather-related requirements and drift monitoring activities. Moreover, applicators should be alert and careful, especially when close to nontarget 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 underreporting 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 because of 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 we combined data from SENSOR-Pesticides and PISP, some duplication of cases and misclassification of variables may have occurred, although we took steps to identify and resolve discrepancies. Also, SENSOR-Pesticides and PISP may differ in case detection sensitivity because 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 insufficient details were entered into the database. We often based the retrospective coding of contributing factors on limited data, which may have produced some misclassification.

Conclusion

These study findings suggest that the incidence of acute illness from off-target pesticide drift exposure was relatively low during 1998–2006 and that most cases presented with low-severity illness. However, the rate of poisoning from pesticide drift was 145 times higher for residents in five agriculture-intensive California counties compared with other counties, and the rate of occupationally exposed cases was 145 times greater in agricultural workers than in nonagricultural 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.

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

| Variable | Drift events (n = 643) | Occupational (n = 1,380) | Nonoccupational (n = 1,565) |
|----------|------------------------|------------------------|--------------------------|
| Violation of federal/state pesticide regulation | 220 (72.6) | 971 (85.6) | 1,122 (93.2) |
| No | 79 (26.4) | 164 (14.4) | 82 (6.9) |
| Applicator carelessness near nontarget sites | 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) |
| Improper seal of fumigation site | 19 (11.6) | 102 (21.0) | 11 (1.0) |
| Inappropriate monitoring | 7 (4.3) | 118 (24.3) | 193 (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 | 2 (1.2) | 125 (25.7) | 2 (0.2) |
| Other | 8 (4.9) | 28 (5.8) | 206 (19.5) |
| Distance from application site | NA | 700 (100) | 728 (100) |
| ≤ 50 feet | 66 (9.4) | 64 (9.4) | 54 (7.4) |
| > 50–100 feet | 77 (11.0) | 29 (4.0) | 69 (9.5) |
| > 100–300 feet | 112 (16.1) | 69 (9.5) | 69 (9.5) |
| > 300 feet–0.25 mile | 267 (38.1) | 93 (12.8) | 93 (12.8) |
| > 0.25–0.5 mile | 175 (25.0) | 256 (35.2) | 256 (35.2) |
| > 0.5–1 mile | 0 (0.0) | 116 (15.9) | 116 (15.9) |
| > 1 mile | 2 (0.3) | 111 (15.2) | 111 (15.2) |

NA, for distance from application site, drift events were not applicable. All percentages for “At least one contributing factor identified” and “Distance from application site” were calculated only for cases with available data.

References

Alarcon WA, Calvert GM, Blondell JM, Mehler LN, Sievert J, Propeck M, et al. 2005. Acute illnesses associated with pesticide exposure at schools. JAMA 294(1):455–465. Association of American Pesticide Control Officials. 2005. 2005 Pesticide Drift Enforcement Survey Report. Available: http://aapco.cers.purdue.edu/doc/surveys/DriftEnforce05Rpt.html (accessed 16 June 2010). Barry T, Driel M, Verdier-Carlos M, Mehler L, Edmiston S, O’Malley M. 2010. Community exposure following a drip-application of chloropicrin. J Agromed 5:1–14. Calvert GM, Karnik J, Mehler L, Beckham J, Morrissey B, Sievert J, et al. 2008. Acute pesticide poisoning among agricultural workers in the United States, 1998–2005. Am J Ind Med 51(12):883–898. Calvert GM, Mehler LN, Alsp J, De Vries AL, Baselli N. 2010. Surveillance of pesticide-related illness and injury in humans. In: Hayes’ Handbook of Pesticide Toxicology (Krieger RJ, ed). 3rd ed. New York:Elsevier, 1313–1369. Calvert GM, Plate DK, Das R, Rosales R, Shafey O, Thomsen C, et al. 2004. Acute occupational pesticide-related illness in the US, 1998–1999: surveillance findings from the SENSOR-Pesticides program. Am J Ind Med 45(1):14–23. CDC (Centers for Disease Control and Prevention). 2004. Brief Report: Illness Associated with Drift of Chloropicrin Soil Fumigant into a Residential Area—Kern County, California. 2003. MMWR Morb Mortal Wkly Rep 53(32):740–742. CDC (Centers for Disease Control and Prevention). 2008. Acute pesticide poisoning associated with pyraclostrobin fungicide—Iowa, 2003. MMWR Morb Mortal Wkly Rep 57(51):1343–1345. CPDR (California Department of Pesticide Regulation) 2001. Pesticide/Wildlife Incident Response Plan Training
Illnesses associated with agricultural pesticide drift

Workbook. Available: http://www.cdpr.ca.gov/docs/county/training/pstfd/pstfdwb.pdf [accessed 16 May 2011].

CDPR (California Department of Pesticide Regulation). 2008. Summary of Results from the California Pesticide Illness Surveillance Program 2006 (HS-1872). Available: http://www.cdpr.ca.gov/docs/whs/pdf/hs1872.pdf [accessed 17 December 2009].

CDPR (California Department of Pesticide Regulation). 2009. Pesticide Use Reporting. Available: http://www.cdpr.ca.gov/docs/pur/purmain.htm [accessed 15 June 2010].

CDPR (California Department of Pesticide Regulation). 2010. DPR Reports Pesticide Use Declined Again in 2008. Available: http://www.cdpr.ca.gov/docs/pressreleases/2010/100107.htm [accessed 15 June 2010].

Council of State and Territorial Epidemiologists. 2010. Introduction and Guide to the Data Tables for Occupational Health Indicators. Available: http://www.cste.org/dmv/programsandactivities/occupationalhealth/occupationalhealthindicators/tabid/85/Default.aspx [accessed 5 July 2010].

Feitshans TA. 1999. An analysis of state pesticide drift laws. San Joaquin Agric L Rev 9:37:37–93.

Goldman P, Brimmer JK, Ruiz V. 2009. Pesticides in the Air—Kids at Risk: Petition to EPA to Protect Children from Pesticide Drift. Available: http://earthjustice.org/sites/default/files/library/legal_docs/petition-pesticides-in-the-air-kids-at-risk.pdf [accessed 17 May 2011].

Harnly ME, Bradman A, Nishioka M, McKane TE, Smith D, McLaughlin R, et al. 2009. Pesticides in dust from homes in an agricultural area. Environ Sci Technol 43(23):8767–8774.

Hofman V, Solseng E. 2001. Reducing Spray Drift. Available: http://www.ag.ndsu.edu/pubs/ae/machine/ae1210w.htm [accessed 16 December 2009].

Hofman V, Solseng E. 2001. Reducing Spray Drift. Available: http://www.ag.ndsu.edu/pubs/ae/machine/ae1210w.htm [accessed 16 December 2009].

O’Malley M, Barry T, Ibarra M, Verder-Carlos M, Mehtler L. 2005. Illnesses related to shank application of metam-sodium, Arvin, California, July 2002. J Agromedicine 10(4):27–42.

Quandt SA, Arcury TA, Rao P, Snively BM, Camann DE, Doran AM, et al. 2004. Agricultural and residential pesticides in wipe samples from farmworker family residences in North Carolina and Virginia. Environ Health Perspect 112:382–387.

U.S. Census Bureau. 1992. 1990 Census of Population and Housing. Alphabetical Index of Industries and Occupations. Washington, DC:U.S. Department of Commerce.

U.S. Census Bureau. 2005. Industry and Occupation 2002. Washington, DC:U.S. Census Bureau. Available: http://www.census.gov/hhes/www/ioindex/ioindex02/view02.html [accessed 30 November 2008].

U.S. Census Bureau. 2009. Current Population Survey. Available: http://www.bls.census.gov/cps_ftp.html [accessed 28 October 2010].

U.S. EPA (U.S. Environmental Protection Agency). 2001. Pesticide Registration (PR) Notice 2001-X Draft: Spray and Dust Drift Label Statements For Pesticide Products. Available: http://www.epa.gov/PR_Notices/prdraft-spraydrift801.htm [accessed 30 November 2009].

U.S. EPA (U.S. Environmental Protection Agency). 2007. Label review manual. Chapter 7. Precautionary statements. Available: http://www.epa.gov/oppfeed/labeling/lrm/chap-07.pdf [accessed 5 July 2011].

U.S. EPA (U.S. Environmental Protection Agency). 2008. Federal Insecticide, Fungicide, and Rodenticide Act [As amended through P.L. 110–246]. Available: http://www.epa.gov/opp00001/regulating/fifra.pdf [accessed 5 July 2011].

U.S. EPA (U.S. Environmental Protection Agency). 2009. Pesticides: Health and Safety—Worker Safety and Training. Available: http://www.epa.gov/opp00001/health/worker.htm [accessed 30 November 2009].

U.S. EPA (U.S. Environmental Protection Agency). 2010. Implementation of Risk Mitigation Measures for Soil Fumigant Pesticides. Available: http://www.epa.gov/opp00001/registration/soil_fumigants/ [accessed 1 November 2010].

Weppner S, Elgethun K, Lu C, Hebert V, Yost MG, Fenske RA. 2006. The Washington aerial spray drift study: children’s exposure to methamidophos in an agricultural community following fixed-wing aircraft applications. J Expo Sci Environ Epidemiol 16(5):387–396.