Acute Illnesses Associated With Pesticide Exposure at Schools

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Context Pesticides continue to be used on school property, and some schools are at risk of pesticide drift exposure from neighboring farms, which leads to pesticide exposure among students and school employees. However, information on the magnitude of illnesses and risk factors associated with these pesticide exposures is not available.

Objective To estimate the magnitude of and associated risk factors for pesticide-related illnesses at schools.

Design, Setting, and Participants Analysis of surveillance data from 1998 to 2002 of 2593 persons with acute pesticide-related illnesses associated with exposure at schools. Nationwide information on pesticide-related illnesses is routinely collected by 3 national pesticide surveillance systems: the National Institute for Occupational Safety and Health's Sentinel Event Notification System for Occupational Risks pesticides program, the California Department of Pesticide Regulation, and the Toxic Exposure Surveillance System.

Main Outcome Measures Incidence rates and severity of acute pesticide-related illnesses.

Results Incidence rates for 1998-2002 were 7.4 cases per million children and 27.3 cases per million school employee full-time equivalents. The incidence rates among children increased significantly from 1998 to 2002. Illness of high severity was found in 3 cases (0.1%), moderate severity in 275 cases (11%), and low severity in 2315 cases (89%). Most illnesses were associated with insecticides (n=895, 35%), disinfectants (n=830, 32%), repellents (n=335, 13%), or herbicides (n=279, 11%). Among 406 cases with detailed information on the source of pesticide exposure, 281 (69%) were associated with pesticides used at schools and 125 (31%) were associated with pesticide drift exposure from farmland.

Conclusions Pesticide exposure at schools produces acute illnesses among school employees and students. To prevent pesticide-related illnesses at schools, implementation of integrated pest management programs in schools, practices to reduce pesticide drift, and adoption of pesticide spray buffer zones around schools are recommended.

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Exposure to pesticides in the school environment is a health risk facing children and school employees. Despite efforts of several organizations and laws in several states to reduce pesticide use at and around schools,[1] pesticides continue to be used in schools.[2] Another source of pesticide exposure at schools is from pesticides used on farmland contiguous to school facilities. However, as a result of the work of the US Environmental Protection Agency (EPA), advocacy groups, universities, state regulators, the pest control industry, and others, and laws or strong voluntary programs in several states, pesticide use has been reduced in some school districts.[3]

Currently, there are no specific federal requirements on limiting pesticide exposures at schools. Under the Federal Insecticide, Fungicide, and Rodenticide Act, pesticides must be regis-

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tered with the EPA before they are sold or distributed.[4] The Food Quality Protection Act[5] of 1996 amended the Federal Insecticide, Fungicide, and Rodenticide Act, bolstering the protection of children through requiring that pesticides used on foods produce no harm. However, there are no specific provisions in these laws about the use of pesticides at schools.[1,6]

The Federal Insecticide, Fungicide, and Rodenticide Act is often supplemented by more stringent state pesticide laws to protect children from pesticides at schools. For example, 18 states recommend (n=6) or require (n=12) schools to use integrated pest management strategies and 7 states restrict pesticide applications in areas neighboring a school.[7] However, there are still large gaps throughout the country where children may not be afforded adequate protection.[1,8]

Pesticide poisoning is a commonly underdiagnosed illness in the United States today. The clinical findings of acute pesticide poisoning are rarely pathognomonic but instead can resemble acute upper respiratory tract illness, conjunctivitis, or gastrointestinal illness, among other conditions. Detailed description of the diverse syndromes associated with different types of pesticides is available.[9]

Although some information about acute illnesses associated with pesticide exposures at schools is available,[10,11] there has not been an effort to provide a nationwide summary of this health problem. To estimate the magnitude of and the risk factors for pesticide-related illnesses associated with exposures at schools, we examined information from state-based pesticide poisoning surveillance systems (the National Institute for Occupational Safety and Health's Sentinel Event Notification System for Occupational Risks [SENSOR] pesticides program and the California Department of Pesticide Regulation [CDPR]), and the Toxic Exposure Surveillance System (TESS), which is a national database of all calls made to poison control centers and is maintained by the American Association of Poison Control Centers.[12,13]

METHODS

Study Design and Participants

School employees, parents, and students who developed acute pesticide-related illnesses from pesticide exposure at child care centers and elementary and secondary schools from 1998 to 2002 were identified (TABLE 1). Data were obtained from states participating in the SENSOR pesticides program (California, Washington, Texas, Florida, Louisiana, New York, Oregon, and Michigan), CDPR (California), and TESS (all US states and District of Columbia, with the exception of Hawaii). The data used in these analyses were surveillance data and as such are exempt from consideration by the human subjects review board and need for informed consent. Integrating data from these 3 surveillance systems provides the best available understanding of the problem of pesticide poisoning at schools. The states participating in the SENSOR and CDPR programs obtain information from multiple sources (government agencies, poison control centers, and reports from health care organizations) and conduct active case follow-up.[12] In addition, all cases identified by the CDPR are referred to the relevant county agricultural commissioner who investigates the exposure circumstances.[10,12] The TESS data are provided by approximately 67 US poison control centers.[13] Approximately 13% of their calls come from physicians treating patients who are exposed and 87% come from patients or their relatives.[12,13]

Table 1. Type of Information Provided by Surveillance Systems, 1998-2002

	Pesticide Surveillance System		
Available Information	SENSOR*	CDPR	TESS†
Occupation of cases provided	Yes	Yes	No
Source of exposure provided (pesticides applied on school grounds vs pesticide drift)	Yes	Yes	No
Nonoccupational cases provided	Yes: Florida, Louisiana, New York, Oregon, Texas, Washington No: California, Michigan	Yes	Yes
Information on disinfectants provided	Yes: Florida, Louisiana, Michigan No: California, New York, Oregon, Texas, Washington	Yes	Yes
Years data were available	1998-2002: California, Florida, Louisiana, New York, Oregon, Texas 2000-2002: Michigan, Washington	1998-2002	1998-2002
Types of schools included	Public and private elementary and secondary schools, child care centers	Public and private elementary and secondary schools, child care centers	Elementary and secondary schools, colleges, universities, child care centers

Abbreviations: CDPR, California Department of Pesticide Regulation; SENSOR, Sentinel Event Notification System for Occupational Risks; TESS, Toxic Exposure Surveillance System.
*Includes Texas, Washington, Florida, Louisiana, California, New York, Oregon, and Michigan.
†Cases included information from all US states and District of Columbia, with the exception of Hawaii.

Cases were included if health effects developed subsequent to pesticide exposure and if these effects were consistent with the known toxicology of the pesticide product, as determined by state surveillance professionals (SENSOR and CDPR cases) or a poison control center specialist (TESS cases). The states participating in the SENSOR pesticides program adopted a standardized case definition in 1998, and CDPR uses a similar case definition. Briefly, the case definition required information on pesticide exposure, health effects, and evidence supporting an association between the pesticide exposure and the health effects. A full description of the standardized case definition has been previously published.[12] Identification of TESS cases relied on the experience and judgment of the poison control center specialist managing the specific case. Multiple cases exposed in a single exposure incident were identified as 1 exposure event. Exclusion criteria included exposure to substances other than pesticides, suicides, intentional abuse, and malicious use.

SENSOR and CDPR primarily capture work-related pesticide poisoning cases, whereas TESS primarily captures non–work-related cases (Table 1). Detailed information on work-related cases was provided by SENSOR and CDPR only. The SENSOR and CDPR cases were further classified into exposure to *pesticides applied on school grounds* when indoor and outdoor pesticide applications on school grounds resulted in illness, and to *pesticide drift* when pesticide drift from applications to neighboring farmland resulted in illness among students and school employees.

For the present analyses, the toxicity category of the pesticide product was retrieved from a data set made available by the EPA. The EPA assigns acute toxicity category I to the most toxic pesticide products and category IV to the least toxic pesticide.[14]

Illness severity was categorized for SENSOR and CDPR cases using standardized criteria.[15] State agencies classified severity for the cases they identified in 2001 and 2002. Two authors (W.A.A. and G.M.C.) assigned severity to 1998-2000 SENSOR cases, all CDPR cases, and all TESS cases.[16] High severity includes cases in which the illness or injury is severe enough to be considered life-threatening and commonly involves hospitalization to prevent death. Signs and symptoms include seizures and pulmonary edema. Moderate severity illness or injury includes cases of less severe illness or injury often involving systemic manifestations requiring treatment. The individual is able to return to normal functioning without any residual disability. Low severity illness or injury typically resolves without treatment and is often manifested by skin, eye, or upper respiratory tract irritation.[15]

Table 2. Characteristics of Acute Pesticide-Related Illnesses by Surveillance Systems, 1998-2002

	No. (%)		
	SENSOR and CDPR (n = 406)	**TESS (n = 2187)**	**Total (N = 2593)**
Age group			
Children	149 (36.7)	1831 (83.7)	1980 (76.4)
Adults	254 (62.6)	274 (12.5)	528 (20.4)
Unknown	3 (0.7)	82 (3.7)	85 (3.3)
Sex			
Female	245 (60.3)	920 (42.1)	1165 (44.9)
Male	143 (35.2)	1166 (53.3)	1309 (50.5)
Unknown	18 (4.4)	101 (4.6)	119 (4.6)
Pesticide toxicity category*			
I	154 (37.9)	183 (8.4)	337 (13.0)
II	49 (12.1)	225 (10.3)	274 (10.6)
III	200 (49.3)	875 (40.0)	1075 (41.5)
Undetermined	3 (0.7)	904 (41.3)	907 (35.0)
Pesticide functional class			
Insecticides only	186 (45.8)	625 (28.6)	811 (31.3)
Insecticides combined†	84 (20.7)	0	84 (3.2)
Disinfectants	99 (24.4)	731 (33.4)	830 (32.0)
Repellents	3 (0.7)	332 (15.2)	335 (12.9)
Herbicides	21 (5.2)	258 (11.8)	279 (10.8)
Fungicides	0	102 (4.7)	102 (3.9)
Rodenticides	0	93 (4.3)	93 (3.6)
Fumigants	9 (2.2)	1 (0.1)	10 (0.4)
Other pesticide class	4 (1.0)	45 (2.0)	49 (1.9)
Severity‡			
High	1 (0.3)	2 (0.1)	3 (0.1)
Moderate	59 (14.5)	216 (9.9)	275 (10.6)
Low	346 (85.2)	1969 (90.0)	2315 (89.3)
Year of exposure			
1998	74 (18.2)	373 (17.1)	447 (17.2)
1999	114 (28.1)	408 (18.7)	522 (20.1)
2000	105 (25.9)	422 (19.3)	527 (20.3)
2001	43 (10.6)	494 (22.6)	537 (20.7)
2002	70 (17.2)	490 (22.4)	560 (21.6)
Total	**406** (15.7)	**2187** (84.3)	**2593** (100.0)

Abbreviations: CDPR, California Department of Pesticide Regulation; SENSOR, Sentinel Event Notification System for Occupational Risks; TESS, Toxic Exposure Surveillance System.
*The US Environmental Protection Agency assigns category I to the most acutely toxic pesticide products and category IV to the least acutely toxic pesticide product.
†Includes cases exposed to insecticides in combination with other pesticides.
‡High severity includes cases in which the illness or injury is severe enough to be considered life-threatening and commonly involves hospitalization to prevent death; moderate severity illness or injury includes cases of less severe illness or injury often involving systemic manifestations requiring treatment (the individual is able to return to normal functioning without any residual disability); and low severity illness or injury is often manifested by skin, eye, or upper respiratory tract irritation (it may also include fever, headache, fatigue, or dizziness) and typically the illness or injury resolves without treatment.

Table 3. Severity of Acute Pesticide-Related Illness and Associated Factors, 1998-2002

	No. (%)		
	Moderate Severity Illness (n = 275)	Low Severity Illness (n = 2315)	Total (N = 2593)*
Age group			
Children	150 (7.6)	1829 (92.4)	1980 (76.4)
Adults	92 (17.4)	434 (82.2)	528 (20.4)
Unknown	33 (38.8)	52 (61.2)	85 (3.3)
Sex			
Female	132 (11.3)	1030 (88.4)	1165 (44.9)
Male	104 (7.9)	1205 (92.1)	1309 (50.5)
Unknown	39 (32.8)	80 (67.2)	119 (4.6)
Pesticide toxicity category†			
I	59 (17.5)	278 (82.5)	337 (13.0)
II	19 (6.9)	255 (93.1)	274 (10.6)
III	129 (12.0)	944 (87.8)	1075 (41.5)
Undetermined	68 (7.5)	838 (92.4)	907 (35.0)
US region‡			
Midwest	86 (13.2)	564 (86.8)	650 (25.1)
Northeast	54 (12.9)	362 (86.6)	418 (16.1)
Southeast	64 (8.4)	701 (91.5)	766 (29.5)
West	69 (9.2)	682 (90.8)	751 (29.0)
Unspecified	2 (25.0)	6 (75.0)	8 (0.3)
Pesticide functional class			
Insecticides only	80 (9.9)	728 (89.8)	811 (31.3)
Insecticides combined§	3 (3.6)	81 (96.4)	84 (3.2)
Disinfectants	101 (12.2)	729 (87.8)	830 (32.0)
Repellents	21 (6.3)	314 (93.7)	335 (12.9)
Herbicides	41 (14.7)	238 (85.3)	279 (10.8)
Fungicides	3 (2.9)	99 (97.1)	102 (3.9)
Rodenticides	2 (2.2)	91 (97.8)	93 (3.6)
Fumigants	4 (40.0)	6 (60.0)	10 (0.4)
Other pesticide class	20 (40.8)	29 (59.2)	49 (1.9)
Pesticide chemical class			
Organophosphorous compound	30 (10.8)	248 (89.2)	278 (10.7)
Organophosphorous combined‖	11 (14.9)	63 (85.1)	74 (2.9)
Inorganic compounds	35 (15.4)	192 (84.6)	227 (8.8)
Inorganic compounds combined‖	3 (30.0)	7 (70.0)	10 (0.4)
Pyrethrins	5 (6.8)	69 (93.2)	74 (2.9)
Pyrethrins combined‖	6 (13.3)	39 (86.7)	45 (1.7)
Indandiones	7 (8.5)	75 (91.5)	82 (3.2)
Indandiones combined‖	3 (11.1)	24 (88.9)	27 (1.0)
Pyrethroids	8 (11.3)	62 (87.3)	71 (2.7)
Pyrethroids combined‖	3 (11.5)	23 (88.5)	26 (1.0)
Chlorophenoxy compounds	2 (2.9)	67 (97.1)	69 (2.7)
Chlorophenoxy compounds combined‖	1 (7.7)	12 (92.3)	13 (0.5)
Carbamates	5 (9.6)	46 (88.5)	52 (2.0)
Other chemical class	140 (9.9)	1275 (90.1)	1415 (54.6)
Unspecified	16 (12.3)	113 (86.9)	130 (5.0)
Total	**275** (10.6)	**2315** (89.3)	**2593** (100.0)

*Three high severity cases are included in the totals.
†See Table 2 for explanation of categories.
‡Midwest region includes Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin; northeast region includes Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont; southeast region includes Alabama, Arkansas, Delaware, District of Columbia, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, and West Virginia; and west region includes Alaska, Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming.
§Includes cases exposed to insecticides combined with other pesticides.
‖Includes cases exposed to multiple chemical classes including organophosphates, inorganic compounds, pyrethrins, pyrethroids, indandiones, or chlorophenoxy compounds.

Data quality control procedures included the elimination of duplicates between SENSOR (California) and CDPR, and between SENSOR and CDPR combined and TESS. To detect duplicates between SENSOR and CDPR combined and TESS, a case-by-case comparison was performed when a reporting source for SENSOR and CDPR cases was a poison control center. Cases that matched each other on state, date of exposure, age, sex, and pesticide name were assumed to involve the same individual. Such individuals were included only once in the state agency totals. Six CDPR and 8 TESS duplicates were deleted.

Data Analysis

SAS release 8.02 (SAS Institute Inc, Cary, NC) and Epi Info version 3.2.2 (Centers for Disease Control and Prevention, Atlanta, Ga) were used for data management and statistical analysis. Age was stratified into children (<18 years) and adults (≥18 years).

Illness incidence rates among children were calculated. Rate numerators were obtained by summing the number of ill children reported by year, and denominators were obtained from the US Census data[17] by summing the number of children in the corresponding state and year. Denominators were adjusted by subtracting estimates of preschoolers not attending organized child care centers[18] and home-schooled children.[19]

Illness incidence rates among school employees were calculated for SENSOR and CDPR cases only. Denominators were obtained from the Current Population Survey[20] by summing the number of full-time equivalents employed in schools in states and years that contributed to the numerator. Non–work-related cases (eg, parents) and cases with unknown work-related status, which included all TESS cases, were not included in these calculations.

We used odds ratios (ORs) to assess whether age, sex, acute toxicity pesticide category, surveillance system, or site of pesticide applications were associated with severity of illness. Odds ratios, 95% confidence intervals (CIs), χ^2 tests, and *P* values were calculated using the Epi Info Statcalc utility. SAS release 8.02 was used to calculate the Poisson regression test for trends in incidence rates across the years of exposure. $P \leq .05$ was considered statistically significant.

RESULTS

From 1998 to 2002, 2593 individuals were identified with acute pesticide-related illnesses associated with pesticide exposures at schools. SENSOR identified 147 cases (6%), CDPR identified 259 cases (10%), and TESS identified 2187 cases (84%) (TABLE 2). Most illnesses reported by SENSOR (n=96, 65%) and CDPR (n=158, 61%) were adults, whereas most cases reported by TESS were children (n=1831, 84%). Among the 2181 persons with known exact age, the mean age for children was 9.5 years (range, 0.5-17.2 years) and the mean age for adults was 36.1 years (range, 18-76 years).

Three cases of high severity illness were identified. There were no fatalities reported. The odds of high and moderate severity illness were higher among cases reported by SENSOR and CDPR (15%) compared with TESS (10%) (OR, 1.6; 95% CI, 1.1-2.2), among adults (18%) compared with children (8%) (OR, 2.6; 95% CI, 2.0-3.5), and among females (12%) compared with males (8%) (OR, 1.5; 95% CI, 1.2-2.0). Moderate severity illness was more common (TABLE 3) among those exposed to fumigants (n=4, 40%), herbicides (n=41, 15%), insecticides (n=83, 9%), and disinfectants (n=101, 12%). TABLE 4 describes symptoms of high and moderate severity cases.

Insecticides were associated with 895 illnesses (Table 2). The most frequent insecticides were pyrethrins (n=119, 13% of all insecticides), chlorpyrifos (n=116, 13%), malathion (n=84, 9%), diazinon (n=78, 9%), and pyrethroids (n=47, 5%). Disinfectants were associated with 830 illnesses. The most frequent disinfectants were sodium hypochlorite (n=175, 21% of all disinfectants), phenol compounds (n=175, 21%), pine oil (n=104, 13%), and quaternary ammonium compounds

Table 4. Clinical Manifestations of Pesticide-Related Illnesses Among Cases of High and Moderate Severity in the United States, 1998-2002*

	No. (%)		
	High Severity Illness (n = 3)	Moderate Severity Illness (n = 275)	High and Moderate Severity Illness (n = 278)
Respiratory	2 (66.7)	133 (48.4)	135 (48.6)
Cough	1 (33.3)	58 (21.1)	59 (21.2)
Dyspnea	1 (33.3)	50 (18.2)	51 (18.3)
Wheezing	1 (33.3)	43 (15.6)	44 (15.8)
Upper respiratory tract pain	2 (66.7)	27 (9.8)	29 (10.4)
Pleuritic pain	0	3 (1.1)	3 (1.1)
Pulmonary edema	1 (33.3)	0	1 (0.4)
Other	1 (33.3)	3 (1.1)	4 (1.4)
Gastrointestinal	1 (33.3)	89 (32.4)	90 (32.4)
Vomiting	1 (33.3)	69 (25.1)	70 (25.2)
Nausea	0	50 (18.2)	50 (18.0)
Abdominal pain	0	10 (3.6)	10 (3.6)
Diarrhea	0	3 (1.1)	3 (1.1)
Other	0	4 (1.5)	4 (1.4)
Nervous system	1 (33.3)	87 (31.6)	88 (31.7)
Headache	0	55 (20.0)	55 (19.8)
Blurred vision	0	26 (9.5)	26 (9.4)
Dizziness	0	10 (3.6)	10 (3.6)
Confusion	0	3 (1.1)	3 (1.1)
Hyperactivity/anxiety/irritability	0	2 (0.7)	2 (0.7)
Muscle weakness	0	2 (0.7)	2 (0.7)
Ataxia	0	1 (0.4)	1 (0.4)
Seizures	1 (33.3)	0	1 (0.4)
Fasciculations	0	1 (0.4)	1 (0.4)
Muscle pain	0	1 (0.4)	1 (0.4)
Other	0	5 (1.8)	5 (1.8)
Eye	0	79 (28.7)	79 (28.4)
Irritation/pain/conjunctivitis	0	74 (26.9)	74 (26.6)
Corneal abrasion	0	11 (4.0)	11 (4.0)
Lacrimation	0	9 (3.3)	9 (3.2)
Burns	0	2 (0.7)	2 (0.7)
Other	0	3 (1.1)	3 (1.1)
Skin	1 (33.3)	30 (10.9)	31 (11.2)
Erythema	1 (33.3)	15 (5.5)	16 (5.8)
Irritation/pain	0	8 (2.9)	8 (2.9)
Pruritus	0	8 (2.9)	8 (2.9)
Edema/swelling	1 (33.3)	6 (2.2)	7 (2.5)
Second- and third-degree burns	0	5 (1.8)	5 (1.8)
Bullae	0	4 (1.5)	4 (1.4)
Rash	0	3 (1.1)	3 (1.1)
Other	0	4 (1.5)	4 (1.4)
Cardiovascular	1 (33.3)	7 (2.5)	8 (2.9)
Tachycardia	1 (33.3)	2 (0.7)	3 (1.1)
Chest pain	0	3 (1.1)	3 (1.1)
Other	0	2 (0.7)	2 (0.7)
Miscellaneous symptoms	2 (66.7)	66 (24.0)	68 (24.5)

*Because more than one clinical effect may have been reported for any person, the sum of the specific effects may not equal the total number reported for the organ system.

(n=81, 10%). Repellents were associated with 335 illnesses, including naphthalene (n=136, 41%) and diethyl toluamide (DEET, n=127, 38%). Herbicides were associated with 279 illnesses, including glyphosate (n=100, 36%), 2,4-dichlorophenoxyacetic acid (n=53, 19%), and pendimethalin (n=40, 14%).

Information on the toxicity category of pesticides associated with illnesses was available for 1686 cases (Table 3). Children were less likely to be exposed to toxicity category I pesticides compared with adults (14% of children and 42% of adults, $P<.001$). The odds of high and moderate severity illness were higher among cases exposed to toxicity category I (18%) than cases exposed to toxicity category III pesticides (12%) (OR, 1.5; 95% CI, 1.1-2.2). The pesticide active ingredients associated with high and moderate severity illness are shown in TABLE 5.

Incidence Rates

The overall incidence rate among children for 1998-2002 was 7.4 cases per million children (TABLE 6). The yearly incidence rates increased from 1998 through 2002 for preschool children ($P<.001$), school-aged children ($P=.002$), and all combined ($P<.001$). The overall incidence rate among adults was 27.3 cases per million full-time equivalents (TABLE 7), and the yearly incidence rates decreased from 1998 through 2002 ($P<.001$).

Table 5. Active Ingredients by Pesticide Functional Class Associated With High and Moderate Illness Severity, 1998-2002*

Pesticide Functional Class	No. (%) High and Moderate Severity Illness (n = 278)	No. (%) Low Severity Illness (n = 2315)	No. (%) Total (N = 2593)†
Insecticides	68 (10.3)	593 (89.7)	661 (100.0)
Pyrethrins	11 (9.2)	108 (90.8)	119 (18.0)
Chlorpyrifos	12 (10.3)	104 (89.7)	116 (17.5)
Malathion	23 (27.4)	61 (72.6)	84 (12.7)
Diazinon	4 (5.1)	74 (94.9)	78 (11.8)
Pyrethroids	11 (23.4)	36 (76.6)	47 (7.1)
Propoxur	2 (33.3)	4 (66.7)	6 (0.9)
Other active ingredient	5 (2.4)	206 (97.6)	211 (31.9)
Disinfectants	82 (14.2)	495 (85.8)	577 (100.0)
Phenol compounds	14 (8.0)	161 (92.0)	175 (30.3)
Sodium hypochlorite	33 (18.9)	142 (81.1)	175 (30.3)
Pine oil	10 (9.6)	94 (90.4)	104 (18.0)
Quaternary ammonium compound	18 (22.2)	63 (77.8)	81 (14.0)
Formaldehyde/hydrogen chloride	5 (29.4)	12 (70.6)	17 (2.9)
Other active ingredient	2 (8.0)	23 (92.0)	25 (4.3)
Repellents	19 (6.4)	276 (93.6)	295 (100.0)
Naphthalene	11 (8.1)	125 (91.9)	136 (46.1)
Diethyl toluamide (DEET)	7 (5.5)	120 (94.5)	127 (43.1)
Other active ingredient	1 (3.1)	31 (96.9)	32 (10.8)
Herbicides	36 (15.0)	204 (85.0)	240 (100.0)
Glyphosate	21 (21.0)	79 (79.0)	100 (41.7)
Pendimethalin	8 (20.0)	32 (80.0)	40 (16.7)
Trifluralin	2 (50.0)	2 (50.0)	4 (1.7)
Other active ingredient	5 (5.2)	91 (94.8)	96 (40.0)
Other pesticide functional class	24 (14.0)	147 (86.0)	171 (100.0)
Total	**229** (11.8)	**1715** (88.2)	**1944** (100.0)

*An active ingredient is one that prevents, destroys, repels, or mitigates a pest, or is a plant regulator, defoliant, desiccant, or nitrogen stabilizer.
†Total number of cases with available information on active ingredients. Note that active ingredient information was not available for all cases.

Illnesses Reported by SENSOR and CDPR

The SENSOR and CDPR results are combined (Table 2) because the case definition and level of detail are similar. A total of 406 persons were exposed to pesticides in 173 events for a mean of 2.3 cases per exposure event (range, 1-61 cases). Eleven exposure events accounted for 208 cases (51%). The 244 work-related cases were exposed in 155 events.

Occupational Illnesses. Among the 244 work-related cases, 144 (59%) were not applying pesticides, 93 (38%) were applying or handling pesticides, and 7 (3%) had no information available. Among the 144 employees not applying pesticides, 96 (67%) were exposed to pesticides applied on school grounds and 48 (33%) were exposed to pesticide drift from neighboring farmland. Sixty-three nonapplicator illnesses (44%) were among teachers. Among the 93 school employees who were applying or handling pesticides, there were 41 custodians and gardeners, 26 food preparation workers, 7 teachers, 7 maintenance workers, and 12 unspecified school employees.

Illnesses Associated With Exposure to Pesticides Applied on School Grounds and Pesticide Drift From Farmland. A total of 281 cases (69%) that were reported to SENSOR and CDPR were exposed to pesticide applications on school grounds (TABLE 8). Insecticides (n=156, 56%) and disinfectants (n=99, 35%) accounted for most of the cases. The most common active ingredients were diazinon (n=64, 23%), sodium hypochlorite (n=47, 17%), chlorpyrifos (n=40, 14%), quaternary ammonium compound (n=38, 14%), and malathion (n=14, 5%).

A total of 125 cases (31%) were exposed to pesticide drift. Insecticides accounted for 114 cases (91%) and fumigants for 9 cases (7%). The most common active ingredients were chlorpyrifos (n=28, 22%), methamidophos combined with chlorothalonil and propargite (n=25, 20%), mancozeb combined with glyphosate (n=20, 16%), cyfluthrin combined with dicofol (n=16, 13%), and malathion (n=13, 10%).

Exposure via pesticide drift compared with pesticides applied on school grounds did not increase the odds of high and moderate severity illness (OR, 0.6; 95% CI, 0.3-1.2; *P*=.09). A higher proportion of children compared with adults were exposed via drift from neighboring farmland (40% vs 25%, *P*=.001).

COMMENT

These findings indicate that pesticide exposures at schools continue to produce acute illnesses among school employees and students in the United States, al-

Table 6. Annual Number and Incidence Rates per Million of Acute Pesticide-Related Illnesses Among Children, 1998-2002*

Region†	Year of Exposure 1998	1999	2000	2001	2002	1998-2002
Midwest						
Cases, No.	68	85	97	127	137	514
Population, No.	12 971 329	12 645 800	12 415 063	12 659 255	12 792 569	63 481 822
Incidence rate, per million	5.2	6.7	7.8	10.0	10.7	8.1
Northeast						
Cases, No.	53	65	105	62	68	353
Population, No.	9 291 895	9 935 145	10 060 770	10 126 121	10 257 622	49 671 552
Incidence rate, per million	5.7	6.5	10.4	6.1	6.6	7.1
Southeast						
Cases, No.	111	141	104	138	126	620
Population, No.	16 576 618	18 298 366	18 211 754	19 014 539	20 583 054	92 684 331
Incidence rate, per million	6.7	7.7	5.7	7.3	6.1	6.7
West						
Cases, No.	52	109	84	134	106	485
Population, No.	11 782 566	11 338 067	11 694 488	12 459 307	12 624 149	59 898 577
Incidence rate, per million	4.4	9.6	7.2	10.8	8.4	8.1
United States						
Cases, No.	284	400	390	461	437	1972‡
Population, No.	50 622 407	52 217 378	52 382 074	54 259 223	56 257 393	265 738 476
Incidence rate, per million	5.6	7.7	7.4	8.5	7.8	7.4

*Includes number of children with pesticide-related illnesses and population in the states that reported cases from 1998 through 2002. Children were younger than 18 years and reported by Sentinel Event Notification System for Occupational Risks, California Department of Pesticide Regulation, and Toxic Exposure Surveillance System.
†Midwest region included Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin; northeast region included Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont; southeast region included Alabama, Arkansas, Delaware, District of Columbia, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, and West Virginia; and west region included Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming.
‡Eight cases are not included in these rates because information on state where the exposure occurred was not available.

Table 7. Annual Number of Acute Pesticide-Related Illnesses and Incidence Rates Among School Employees, Preschool, and School-Aged Children, 1998-2002*

	Year of Exposure 1998	1999	2000	2001	2002	Overall
Workers (≥18 years)						
Cases, No.	68	42	54	20	60	244
Full-time equivalents, No.	1 532 876	1 329 312	2 023 135	1 727 500	2 325 209	8 938 032
Incidence rate†	44.4	31.6	26.7	11.6	25.8	27.3
Preschool (0-5 years)						
Cases, No.	59	76	68	84	104	391
Population, No.‡	5 220 556	5 659 786	3 587 875	5 053 894	4 626 154	24 148 266
Incidence rate, per million	11.3	13.4	19.0	16.6	22.5	16.2
School-aged (6-17 years)						
Cases, No.	225	324	322	377	333	1581
Population, No.§	45 401 851	46 557 592	48 794 199	49 205 329	51 631 239	241 590 210
Incidence rate, per million	5.0	7.0	6.6	7.7	6.4	6.5

*School employees were reported by Sentinel Event Notification System for Occupational Risks and California Department of Pesticide Regulation, and includes the states of California, Florida, Louisiana, Michigan, New York, Oregon, Texas, and Washington. Preschool and school-aged children were reported by Sentinel Event Notification System for Occupational Risks and California Department of Pesticide Regulation, and Toxic Exposure Surveillance System, which includes all US states and District of Columbia, with the exception of Hawaii.
†Per million full-time equivalents.
‡Estimated number of preschool children attending day care centers, nursery preschool, Headstart, family day care, or school.
§Number of children attending school, excluding home-schooled children.

beit mainly of low severity and with relatively low incidence rates. Illnesses were associated with pesticides applied on school grounds and with pesticide drift from neighboring farmland. The pesticide exposures at schools might be associated in part with several factors: a lack of federal and state regulations regarding pesticide usage in schools[1]; regulatory noncompliance by school management, school employees, and pesticide applicators in states in which regulations and recommendations have been passed; and insufficient involvement of stakeholders (eg, parents, teachers, students, school administrators, pest managers).[6]

We found that the pesticide poisoning incidence rates among children increased during the period of our report. Given that 40% (n=59) of SENSOR and CDPR cases involving children were exposed to pesticide drift and, given increasing suburban sprawl, this trend among children might be related to an increased number of schools situated next to farmland.[6] Additional studies are needed to confirm this hypothesis. Hypotheses for the decreasing trend in illness rates among school employees include changes in pesticide use practices and increased awareness of the toxic effects of pesticides.

Incidence rates among school employees were found to be higher than incidence rates among children. Possible explanations include school employees are called to protect children when incidents occur, whereas students are often quickly evacuated; school employees are at schools for more hours compared with students; and some school employees handle or apply pesticides.

Based on SENSOR and CDPR data, most cases of acute pesticide-related illnesses were associated with pesticides applied on school grounds (n=281, 69%). Repeated pesticide applications on school grounds raise concerns about persistent low level exposures to pesticides at schools. It is known that some pesticides degrade slowly when they are not exposed to sun, rain, and bacterial action in the soil.[21-24] In addition, pesticide residues on the school grounds might be tracked into school buildings by students and school employees. The chronic long-term impacts of pesticide exposures have not been comprehensively evaluated; therefore, the potential for chronic health effects from pesticide exposures at schools should not be dismissed.[25] Unfortunately, the surveillance methods used in our report are inadequate for assessing chronic effects.

Table 8. Exposure to Pesticides Applied on School Grounds vs Pesticide Drift From Farmland in the United States, 1998-2002*

	No. (%)		
	Pesticides Applied on School Grounds (n = 281)	Pesticide Drift From Farmland (n = 125)	Total (N = 406)
Surveillance system			
SENSOR	75 (26.7)	72 (57.6)	147 (36.2)
CDPR	206 (73.3)	53 (42.4)	259 (63.8)
Severity			
High	1 (0.4)	0	1 (0.3)
Moderate	46 (16.4)	13 (10.4)	59 (14.5)
Low	234 (83.3)	112 (89.6)	346 (85.2)
Age group			
Children	90 (32.0)	59 (47.2)	149 (36.7)
Adults	191 (68.0)	63 (50.4)	254 (62.6)
Unknown	0	3 (2.4)	3 (0.7)
Work-relatedness			
Work-related	190 (67.6)	54 (43.2)	244 (60.1)
Non–work-related	91 (32.4)	68 (54.4)	159 (39.2)
Unknown	0	3 (2.4)	3 (0.7)
Occupation			
Student	84 (29.9)	62 (49.6)	146 (36.0)
Teacher	41 (14.6)	35 (28.0)	76 (18.7)
Custodian and gardener†	43 (15.3)	1 (0.8)	44 (10.8)
Food preparation occupations	32 (11.4)	1 (0.8)	33 (8.1)
Maintenance worker	12 (4.3)	0	12 (3.0)
Parent	1 (0.4)	5 (4.0)	6 (1.5)
Other occupations	60 (21.4)	17 (13.6)	77 (19.0)
Not applicable‡	5 (1.8)	0	5 (1.2)
Unknown	3 (1.1)	4 (3.2)	7 (1.7)
Pesticide toxicity category§			
I	96 (34.2)	58 (46.4)	154 (37.9)
II	46 (16.4)	3 (2.4)	49 (12.1)
III	136 (48.4)	64 (51.2)	200 (49.3)
Undetermined	3 (1.1)	0	3 (0.7)
Pesticide functional class			
Insecticides only	140 (49.8)	46 (36.8)	186 (45.8)
Insecticides combined‖	16 (5.7)	68 (54.4)	84 (20.7)
Disinfectants	99 (35.2)	0	99 (24.4)
Herbicides	20 (7.1)	1 (0.8)	21 (5.2)
Fumigants	0	9 (7.2)	9 (2.2)
Repellents	3 (1.1)	0	3 (0.7)
Other	3 (1.1)	1 (0.8)	4 (1.0)
Total	**281** (69.2)	**125** (30.8)	**406** (100.0)

Abbreviations: CDPR, California Department of Pesticide Regulation; SENSOR, Sentinel Event Notification System for Occupational Risks.
*Pesticide exposure due to pesticide applications on school grounds and pesticide drift from neighboring farm fields.
†Includes 6 gardeners.
‡Children younger than 5 years.
§See Table 2 for explanation of categories.
‖Includes cases exposed to insecticides combined with other pesticides.

Although insecticides were most frequently associated with pesticide-related illnesses (n=895, 35%), we found that exposure to disinfectants at schools might also be a cause for concern. First, disinfectants accounted for 830 (32%) of 2593 total cases and for 101 (37%) of 275 moderate severity cases. Second, 259 (56%) of 461 cases of disinfectant exposure with toxicity category available were of toxicity category I. Finally, most of the disinfectants associated with moderate illnesses were products commonly used at schools (sodium hypochlorite and quaternary ammonium compounds).

We also found acute illnesses associated with exposure to pesticide drift from neighboring farmland. These exposures might have resulted from pesticide applicators not complying with pesticide labels, regulations, and/or guidance to avoid pesticide spray drift, or lack of federal and state regulations regarding pesticide application around schools. Additionally, pesticide drift from neighboring farm fields might increase pesticide exposure inside schools. Some studies[26-29] suggest that dwellings adjacent to fields can be contaminated by pesticide drift during applications and subsequent wind recirculation of dust from the fields.

To prevent illnesses associated with pesticide applications on or near school grounds, there is a need to reduce pesticide use. This can be accomplished by implementing integrated pest management at schools and using methods that reduce pesticide drift from farmland. Integrated pest management programs can reduce pesticide use at schools.[3,30] Integrated pest management is endorsed by the EPA,[3] National Parent Teacher Association,[31] National Education Association, and other organizations. The elements of integrated pest management are detailed in the Box. Useful guidance and references on integrated pest management in schools are widely available.[3,32] Some disadvantages of integrated pest management implementation include the requirements of more involvement of school employees, parents, and students, and the need to be educated on pest biology and integrated pest management. Finally, some economic investment is usually required at the outset of an integrated pest management program. However, over the long term, the costs of integrated pest management have been found to be lower than traditional pest control.[3,30]

We tried to identify illness rate differences among children across states with different integrated pest management laws (mandatory, voluntary, without laws). However, this comparison was not meaningful because these laws have tremendous variation across states in terms of coverage, enforcement, and

Box. Recommendations to Reduce Pesticide Exposures at Schools

Pesticides Applied on School Property

Implement school integrated pest management programs:

- Monitor for pest problems.
- Identify the sources of any pest problems.
- Eliminate the sources of any pest problems, using pesticides only as a last resort. Use nontoxic methods, such as ensuring sanitary conditions and structural integrity.
- If nontoxic pest control methods are impractical or unsuccessful, then use pesticides having the lowest possible toxicity. Pesticides in US Environmental Protection Agency toxicity categories I and II should be avoided if possible. If pesticides are used:
  - Provide prior written notification of the application.
  - Post notices in designated areas at the school.
  - Students and staff should not be present during pesticide applications.
  - Restrict entry into a previously treated area for a specified duration following an application.
- Call a poison control center or seek medical attention if pesticide-related illnesses arise.
- Trained and qualified workers should handle and apply pesticides. They must be provided with appropriate safety equipment.
- Put the school's policy on pest control in writing and distribute it to school stakeholders periodically (eg, at the beginning of the school year).
- Involve and train stakeholders (school management, parents, teachers, students, and pesticide applicators).

Pesticide Drift From Neighboring Farmland

Reduce or eliminate application methods that result in drift.

Timing of pesticide applications. Applications should be performed when students and school employees are not present.

Farmers and pesticide applicators should comply with labels, regulations, and guidance to avoid pesticide spray drift.

Pesticides should be applied by trained applicators.

Establish and enforce nonspray buffer zones around schools. Size of buffer zone depends on toxicity of pesticide, type of application (ground or aerial), and weather conditions. For example, 7 states require buffer zones ranging from 300 feet to 2.5 miles around schools.

Underreporting

Improvement in pesticide poisoning surveillance is needed. Every state should implement an acute pesticide-related illness surveillance system.

Acute pesticide-related illnesses should be a reportable condition in all states.

implementation. Additionally, 40% of cases among children in SENSOR and CDPR were exposed to pesticide drift. A similar proportion of children in the entire data set might have been exposed to pesticide drift but these cases could not be identified in TESS. Integrated pest management practices in schools are not designed to prevent exposures to pesticide drift. There were too few SENSOR and CDPR cases involving onsite applications in schools (n=281) to assess integrated pest management laws.

Our findings are subject to at least 3 limitations. First, these results should be considered low estimates of the magnitude of the problem because many cases of pesticide poisoning are likely not reported to surveillance systems or poison control centers. Individuals who do not seek medical care or report their illness to a surveillance system or a poison control center will not be identified. Even when individuals seek medical care, their illness may not be recognized as pesticide-related, because of the nonpathognomonic nature of the signs and symptoms and because clinicians receive little training on these illnesses.[33,34] Second, although all of these cases met the definition criteria, the possibility of some false-positives cannot be excluded. Given both the nonspecificity of the clinical findings of pesticide poisoning and the lack of a criterion standard diagnostic test, some illnesses temporally related to pesticide exposures may be coincidental and not caused by these exposures. Third, although the case definition was similar, some characteristics of the populations reported by these 3 systems were different. TESS was efficient in capturing data for children, but it did not collect information on occupation, work-relatedness, and the activity the person was performing when exposed to pesticides. The SENSOR and CDPR data apply to 8 states and principally identify work-related cases. Not all states participating in SENSOR collect information on nonoccupational cases; therefore, many cases among children were likely missed by SENSOR and CDPR. None of these data sources are comprehensive. The literature suggests that less than one third of poisoning cases treated in health care facilities are reported to poison control centers and in states where SENSOR and TESS systems are in place, TESS identified only 10% of the cases identified by SENSOR.[35]

In conclusion, despite the limitations of these 3 surveillance systems, our report is useful in providing national estimates of the magnitude of pesticide-related illnesses among school employees and students, and in identifying the risk factors that should be targeted for prevention. Strategies recommended to reduce pesticide exposures at schools include adopting integrated pest management programs and using methods to reduce pesticide drift from farmland.

Author Contributions: Dr Alarcon had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.
Study concept and design: Alarcon, Calvert.
Acquisition of data: Calvert, Blondell, Mehler, Sievert, Propeck, Tibbetts, Becker, Lackovic, Soileau, Das, Beckman, Male, Thomsen, Stanbury.
Analysis and interpretation of data: Alarcon, Calvert.
Drafting of the manuscript: Alarcon, Calvert.
Critical revision of the manuscript for important intellectual content: Alarcon, Calvert, Blondell, Mehler, Sievert, Propeck, Tibbetts, Becker, Lackovic, Soileau, Das, Beckman, Male, Thomsen, Stanbury.
Statistical analysis: Alarcon.
Administrative, technical, or material support: Alarcon, Calvert, Blondell, Mehler, Sievert, Propeck, Tibbetts, Becker, Lackovic, Soileau, Beckman, Male, Thomsen, Stanbury.
Study supervision: Calvert.

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Words are chameleons, which reflect the color of their environment.
—Learned Hand (1872-1961)

men determine the right thing to do if they develop prostate cancer.

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CORRECTIONS

Omitted Author Degree: In the Original Contribution entitled "Acute Illnesses Associated With Pesticide Exposure at Schools" published in the July 27, 2005, issue of *JAMA* (2005;294:455-465), an author's second degree was missing in the byline. The byline should have read Alan Becker, MPH, PhD.

Incorrect Data in Table: In the Original Contribution entitled "Noninvasive Coronary Angiography With Multislice Computed Tomography" published in the May 25, 2005, issue of *JAMA* (2005;293:2471-2478), the data in the last 2 columns of **Table 3** on page 2475 were incorrect. These data should have read as follows:

Table 3. Diagnostic Accuracy of MSCT to Detect Stenoses of >50% Lumen Diameter Reduction

Patients*	Patients†
58	45
56	43
7	2
2	2
56/58 (96 [88.1-99.6])	43/45 (95 [89.5-100])
38/45 (84 [70.6-93.5])	28/30 (93 [84.4-100])
56/63 (89 [78.4-95.4])	43/45 (95 [89.5-100])
38/40 (95 [83.1-99.4])	28/30 (93 [84.4-100])

*Including all patients for the analysis.
†Excluding 28 of 103 patients (27%) with only partial coronary tree coverage available.

I am a soldier, convinced that I am acting on behalf of soldiers. I believe that this war, upon which I entered as a war of defense and liberation, has now become a war of aggression and conquest. I believe that the purposes for which I and my fellow-soldiers entered upon this war should have been so clearly stated as to have made it impossible to change them, and that, had this been done, the objects which actuated us would now be attainable by negotiation.

—Siegfried Sassoon (1886-1967)

