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ABSTRACT
In the United States, there is limited literature on occupational pesticide exposures despite being associated with adverse health outcomes, including in large states such as Texas. The purpose of this article is to characterize occupational pesticide poison center exposures in Texas. Descriptive statistics were used to describe exposures (eg, exposure routes, type of pesticide, medical outcome, clinical effects, and temporal/seasonal patterns). From 2000 to 2015, there were 2,303 occupational pesticide poison center exposures. Common types of reported pesticides were insecticides (67.3%), herbicides (17.7%), and repellents (5.8%). The highest proportion of exposures were among those aged 20 to 29 years (24.9%). The top clinical effect categories were gastrointestinal (25.8%), neurological (19.2%), and dermal (14.9%). Characterizing occupational pesticide poison center exposures can support improved surveillance systems and guide future research or interventions.

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Pesticide is defined by the United States Environmental Protection Agency (US EPA) as a substance with an active ingredient that "prevents, destroys, repels, or mitigates a pest" or that is "a plant regulator, defoliant, desiccant, or nitrogen stabilizer."[1] Pesticides help with food production by assisting with crop production and preserving foods, as well as controlling insects and diseases.[2] Pesticides have many benefits, but they can also be harmful to those exposed.[2] Despite being the ninth most common substance category reported to US poison control centers, there is limited information on pesticide exposures in the United States, including occupational exposures.[3]

Occupational pesticide exposures can occur through the production, transportation, and application of pesticides.[4] According to the US EPA, there are 10,000–20,000 physician-diagnosed pesticide poisonings annually among agricultural workers.[2] In addition to agricultural workers, a variety of other occupations are at risk of pesticide exposures, such as groundskeepers, pet groomers, and fumigators.[2] According to the US Department of Labor Bureau of Labor Statistics, there are 25,230 individuals employed in occupations that mix or apply pesticides, herbicides, fungicides, or insecticides in the United States.[5] Of these, Texas has the fifth-highest number of employees with 1,160, following California ($n = 3{,}090$), Florida ($n = 2{,}610$), Illinois ($n = 1{,}350$), and Iowa ($n = 1{,}170$).[5]

There is a multitude of acute (eg, headaches, dizziness, nausea) and chronic (eg, Parkinson's disease, cancers, reproductive health outcomes) health effects linked to pesticide exposures.[6–11] These associated health effects are supported by studies conducted by AGRICOH, which is an international consortium of agricultural cohort studies that focuses on identifying adverse health effects associated with farm work and pesticide exposures, such as cancer, respiratory diseases, neurologic diseases, reproductive health, allergic disorders, cardiovascular diseases, injuries, and autoimmune diseases.[12] Participating agricultural cohorts in the United States include the Center for the Health Assessment of Mothers and Children of Salinas (CHAMACOS) cohort, Farmers Health Study, Mexican Immigration to California Agricultural Safety and Acculturation (MICASA) study, Next Generation Cohort of Agricultural Health Study, Keokuk County Rural Health, The Marshfield Epidemiologic Study Area (MESA) cohort, and the Agricultural Health Study (AHS).[12]

At the national level, there is limited surveillance of occupational pesticide exposures in the United States. The National Poison Data System (NPDS), maintained by the American Association of Poison Control Centers (AAPCC), collects information on all exposures/poisonings reported to poison centers in the United States, including pesticides.[13] In addition, the National Institute for Occupational Safety and Health (NIOSH) and state

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health departments conduct cooperative surveillance of occupational illnesses and injuries through the Sentinel Event Notification System for Occupational Risk (SENSOR) program, including pesticide illnesses and injuries.[14] Texas is a federally unfunded SENSOR-pesticide partner, which requires reporting of occupational pesticide illnesses and injuries to NIOSH. This is accomplished through the Texas Department of State Health Services (DSHS) Pesticide Exposure Surveillance in Texas (PEST) program, which maintains a database for acute occupational pesticide poisonings.[14,15] All states that participate in SENSOR require physicians to report confirmed and suspected cases of pesticide exposures that meet the SENSOR case definition for occupational pesticide-related illness or injury, which includes anybody that was exposed to 1or more pesticides at the person's workplace.[16] SENSOR publications typically include only confirmed illness and injury cases because other exposures do not contain sufficient information.[16]

There have been very few studies that have utilized existing surveillance data, including poison center, SENSOR, and hospitalization data, to research pesticide exposures, with even fewer focusing on occupational exposures specifically in Texas.[16–28] Calvert and colleagues reported on acute occupational pesticide illnesses and injuries in the United States from 2007 to 2010 and 2007 to 2011 utilizing SENSOR-pesticide program data from 12 states (California, Florida, Iowa, Louisiana, Michigan, Nebraska, New Mexico, New York, North Carolina, Oregon, Texas, Washington).[16,17] The most recent study identified 2,606 occupational pesticide illnesses and injuries from 2007 to 2011.[16] Of those, 363 (13.93%) were in Texas, which had the third-highest count, following California ($n = 858$) and Washington ($n = 464$).[16] However, accounting for full-time equivalents, Texas had the ninth-highest incidence rate (FTEs) at 0.7 per 100,000 FTE.[16] The highest incidence rate was for Washington, at 3.1 per 100,000 FTE.[16] Relative to neighboring states with SENSOR data, Texas had the highest raw count compared to Louisiana ($n = 98$) and New Mexico ($n = 9$); however, Louisiana had the highest incidence rate at 1.0 per 100,000 FTE.[16]

Even with programs and large cohort studies collecting and reporting information on occupational pesticide illness and injuries, there is limited surveillance information on these exposures in the United States, specifically in Texas. Litovitz and colleagues utilized data from the AAPCC to identify reported occupational and environmental exposures. It is important to note this manuscript was published over 20 years ago.[29] Despite its age, this manuscript highlighted many benefits of utilizing poison center data, including that cases from small worksites may not be captured in other surveillance data, anonymity encourages reporting, and the database focuses on individual exposures, not a selected population or defined exposure. Consequently, poison center data can help fill a void where there is minimal surveillance.[29] This article attempts to utilize poison center data to characterize acute occupational pesticide poison center exposures in Texas over an extended period, 2000–2015.

Methods

Data collection

The study utilized poison center exposure data from the Texas Poison Center Network (TPCN) from 2000 to 2015. The TPCN is composed of 6 regional poison centers that serve the entire state of Texas, a population of over 25 million.[30] For this study, *occupational pesticide poison center exposures* were defined as all exposures classified as pesticides that involved patients age $\geq$ 13 years that had an exposure site classified as "workplace" or exposure reason classified as "unintentional occupational." *Pesticide exposures* were defined as exposures where the generic code field used to code the substance(s) involved in the exposure was a pesticide code. The AAPCC utilizes a coding database that categorizes substances involved in exposures into common generic codes based on their category (eg, pesticides).[31] The generic code was utilized to identify all pesticide cases as well as to classify occupational pesticide poison center exposures into type of pesticide (eg, insecticide, rodenticide, fumigant, herbicide, repellent). Variables included in the study were type of pesticide, year, month, age category, gender, exposure route, management site, medical outcome, and clinical effect. Exposure route, management site, and medical outcome followed categories provided by the AAPCC.[3]

The medical outcome or severity of an exposure is assigned by the poison center staff and is based on the observed or anticipated adverse clinical effects. Medical outcome is classified according to the following criteria: no effect (no symptoms due to exposure), minor effect (some minimally troublesome symptoms), moderate effect (more pronounced, prolonged symptoms), major effect (symptoms that are life threatening or cause significant disability or disfigurement), and death. A portion of exposures are not followed to a final medical outcome because the exposure was expected to be nontoxic or minimal or because of the inability to obtain subsequent information on the patient, such as patient was lost to follow-up, refused follow-up, or was not followed.[3] In these instances, the poison center staff recorded the expected outcome of the exposure. Expected outcomes are grouped into the following categories: not followed but judged as nontoxic exposure (symptoms not expected), not followed but minimal symptoms possible (no more than minor symptoms possible), unable to follow but judged as a potentially toxic exposure. Another medical outcome category is "unrelated effect," which is used when the exposure was probably not responsible for the symptoms.

Clinical effects were condensed to affected organ system groups: gastrointestinal, neurological, dermal, ocular, respiratory, cardiovascular, renal, hematology/hepatic, and miscellaneous. Seasons were defined as spring (March–May), summer (June–August), fall (September–November), and winter (December–February).

The methods utilized are in line with the minimum data collection guidelines provided by NIOSH.[32] However, Current Population Survey Data from the Bureau of Labor Statistics for number of employees could not be utilized since the poison center data utilized has predefined age categories that were not in line with available employment data. Texas population data for gender and age groups were obtained from the 2010 Census data on American FactFinder through the United States Census Bureau.[33] This population data source does not account for the number of individuals employed in each group, which is a limitation of the analysis.

This study could not examine the effects of dose of pesticide because this information was not available for a majority of exposures. In addition, type of occupation was not examined because the occupation or industry was not typically collected on the exposures and thus was not analyzed.

Statistical analysis

Frequencies were calculated for all variables utilizing Microsoft Excel 2016.

Ethical conduct of research

The Texas Department of State Health Services (DSHS) provided aggregate data utilized for this article. The research is covered by the Texas DSHS Institutional Review Board (IRB # 05–018).

Results

There were 2,303 occupational pesticide poison center exposures from 2000 to 2015 in Texas. Of the exposures, 66.1% ($n = 1{,}522$) were coded as "exposure site workplace" and exposure reason "unintentional occupational." The remaining exposures were coded as "exposure site workplace" with a different exposure reason (nonoccupational) reported (32.6%; $n = 751$) or coded as exposure reason "unintentional occupational" and a nonworkplace exposure site reported (1.3%; $n = 30$). If the exposure reason "unintentional occupational" was utilized alone to pull cases, 67.4% ($n = 1{,}552$) of cases would have been captured. Whereas if only exposure site "workplace" was utilized, 98.7% ($n = 2{,}273$) of the cases would have been captured.

The age categories of reported pesticide poison center exposures by gender are shown in Table 1. Of all of the exposures, the majority of patients were male (73.9%; $n = 1{,}702$) compared to female (24.8%; $n = 572$). For both males and females, those aged 20–29 years had the highest percentage of pesticide exposures, which accounted for 24.9% ($n = 573$) of occupational pesticide poison center exposures. The next top 3 age categories were 30–39 years, 40–49 years, and 50–59 years. Adolescents ≤ 19 years and adults ≥ 60 years each represented approximately 6% of occupational pesticide poison center exposures. Those 13–19 years, 50–59 years, and ≥ 60 years were underrepresented compared to the reported Texas population. However, those aged 20–29 years and 30–39 years had a higher proportion of cases compared to the population size in those groups.

According to the generic code groupings, the 5 most common types of pesticides reported were insecticides (67.3%; $n = 1{,}549$), herbicides (17.7%; $n = 407$), repellents (5.8%; $n = 134$), fumigants (3.7%; $n = 86$), and fungicides (3.5%; $n = 81$). The reported exposure routes were inhalation (49.1%; $n = 1{,}130$), dermal

Table 1. Patient age and gender for occupational pesticide-related poison center exposures in Texas, 2000–2015.

Age Category (years)	Male		Percentage of Texas male population aged ≥ 13 years	Female		Percentage of Texas female population aged ≥ 13 years	Unknown		Total age category		Percentage of Texas population aged ≥13 years
	n	%		*n*	%		*n*	%	*n*	%	
13–19	115	5.0	10.82	27	1.2	10.08	0	0.0	142	6.2	13.03
20–29	441	19.1	15.00	132	5.7	14.19	0	0.0	573	24.9	18.21
30–39	344	14.9	14.01	116	5.0	13.93	1	0.0	461	20.0	17.49
40–49	285	12.4	13.74	108	4.7	13.68	0	0.0	393	17.1	17.15
50–59	176	7.6	12.32	68	3.0	12.18	0	0.0	244	10.6	15.37
≥ 60	108	4.7	15.02	25	1.1	13.64	0	0.0	133	5.8	18.74
Unknown adult	233	10.1	0.00	96	4.2	0.00	28	1.2	357	15.5	0.00
Total	1,702	73.9	79.55	572	24.8	80.71	29	1.3	2,303	100.0	80.13

(45.9%; $n = 1{,}057$), ingestion (15.2%; $n = 351$), ocular (14.5%; $n = 334$), unknown (1.3%; $n = 30$), bite (0.1%; $n = 2$), parenteral (0.1%; $n = 3$), and otic (0.1%; $n = 2$) (data not shown). The sum of percentages for exposure routes exceeds 100% because exposures can report more than one exposure route. When analyzed by gender, the top exposure routes for males were dermal (50.4%; $n = 857$), inhalation (45.7%; $n = 777$), and ingestion (16.2%; $n = 275$). The top exposure routes for females were inhalation (57.2%; $n = 327$), dermal (34.4%; $n = 197$), and ingestion (13.3%; $n = 76$). The other exposure routes had similar distributions for males and females.

Approximately half of the exposures (50.8%; $n = 1{,}171$) required management at a health care facility (data not shown). Of the total exposures, 41.0% ($n = 945$) were at or in route to a health care facility when the poison center was contacted, and 9.8% ($n = 226$) were referred by poison center to a health care facility. Of the remaining exposures, 46.1% ($n = 1{,}062$) were managed on site (outside of a health care facility) and 3.0% ($n = 60$) were managed at an unspecified other or unknown site. The top medical outcome categories included (1) minor effect, (2) unable to follow, judged as a potentially toxic exposures, and (3) moderate effect (Table 2). Of the top 3 medical outcome categories, 8% were cases that were unable to be followed but were expected to be potentially toxic exposures. The distribution of clinical effect categories is shown in Table 3.

The distribution of occupational pesticide poison center exposures by year is shown in Figure 1. There was an average of 144 occupational pesticide poison center exposures reported annually (range 107–202). There were no clear temporal trends observed. Overall from 2000–2015, reported exposures decreased from 168 to 149, with the year of highest reported exposures being 2007 ($n = 202$). When split by season, 67.0% of occupational pesticide exposures occurred in the spring (29.8%; $n = 686$) and summer (37.2%; $n = 856$). The remaining exposures occurred in the fall (22.5%; $n = 518$) and winter (10.6%; $n = 243$).

Table 2. Medical outcomes for occupational pesticide-related poison center exposures in Texas, 2000–2015.

Medical outcome	*n*	%
No effect	239	10.4
Minor effect	659	28.6
Moderate effect	253	11.0
Major effect	16	0.7
Death	1	0.0
Not followed, judged as nontoxic exposure (clinical effects not expected)	36	1.6
Not followed, minimal clinical effects possible (no more than minor effect possible)	686	29.8
Unable to follow, judged as a potentially toxic exposure	185	8.0
Unrelated effect, the exposure was probably not responsible for the effect(s)	228	9.9

Table 3. Clinical effect categories for occupational pesticide-related poison center exposures in Texas, 2000–2015.

Clinical effect	*n*	%
Cardiovascular	154	5.0
Dermal	426	13.9
Gastrointestinal	712	23.3
Hematology/hepatic	3	0.1
Miscellaneous	469	15.3
Neurological	610	19.9
Ocular	374	12.2
Renal	18	0.6
Respiratory	293	9.6

Comment

This study found that, when utilizing poison center data to research occupational pesticide exposures, both occupational exposure reason and workplace for exposure site, in combination, should be utilized to capture as many reported occupational pesticide exposures as possible. Approximately 66% of occupational pesticide exposures represented in this article were flagged as "unintentional occupational" with exposure site being the workplace. Thus, if exposure reason and exposure site were not pulled separately, 34% of the cases would not have been identified. This is supported by the pesticide illness and injury surveillance guidelines provided by NIOSH.[33] Future surveillance systems and research can be improved through understanding potential limitations and advantages of pulling cases using different definitions.

This study identified patterns in the data that can support improved surveillance systems and guide future research or interventions. The majority of those involved in occupational pesticide poison center exposures were male (73.9%). In the State of Texas, males account for 49.2% of those aged ≥ 13 years and 42.3% of those in the civilian workforce aged ≥ 16 years, both of which are markedly less than the percentage of males in this analysis and may reflect gender differences in occupations that utilize pesticides.[33] Demographic data for employees in occupational groups prone to pesticide exposures is limited, in Texas, to farmworkers, and national statistics, which also are more focused on farmworkers. The United States Department of Agriculture (USDA) Economic Research Service (ERS) found that males accounted for 82% of hired farmworkers in 2012.[34] The 2013–2014 National Agricultural Workers Survey found that 72% of respondents were male.[35] This larger

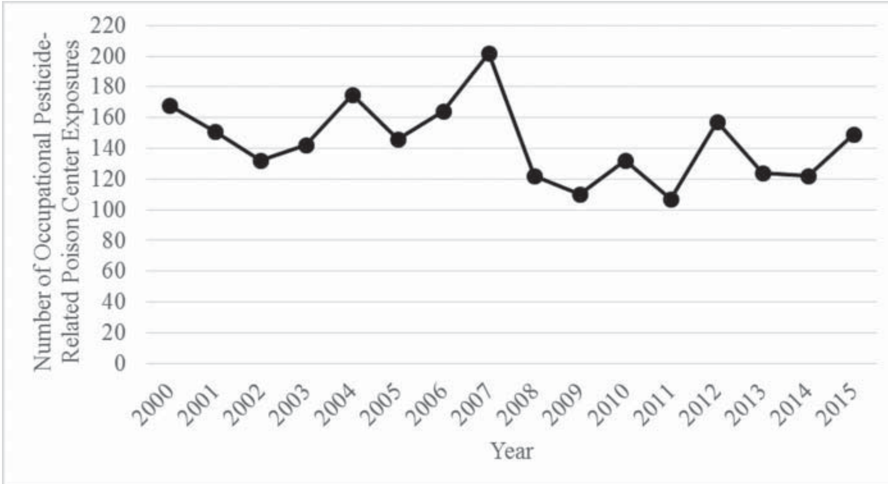

Figure 1. Number of occupational pesticide-related poison center exposures in Texas by year, 2000–2015.

proportion of males is consistent with other reports.[16–18,20,21] Calvert and colleagues found that males accounted for 66.5% of occupational pesticide exposures in their study.[16] Gender differences are important to consider when designing interventions due to potential gender differences in the workforce (eg, more males) and different risk factors, such as differences in crops and tasks performed.[21]

In this study, pesticide exposures were not similarly distributed to the Texas population across age categories. For example, those aged 13–19 years, 50–59 years, and ≥ 60 years were underrepresented while those aged 20–29 years and 30–39 years were overrepresented. However, this under- and overrepresentation is consistent with known characteristics of farmworkers in the United States.[34,35] The ERS found in 2012 that the median age of farmworkers was 35 years.[34] In addition, 25% of farmworkers were under the age of 25 whereas 31% of farmworkers were over the age of 44.[34] Those who were 13–19 years old, 50–59 years old, and ≥ 60 years old were most likely underrepresented in the present study because these age groups are the least likely to be performing farm work. This finding is supported by the 2013–2014 National Agricultural Workers Survey (NAWS), which found that of those surveyed, 17% were 14–24 years old, 27% were 25–34 years old, 24% were 35–44 years old, 18% were 45–54 years old, and 14% were 55 or older.[35] Age is another important factor to consider when designing interventions and determining the best method to reach the intended group.

This study found that the 2 most common types of pesticides were insecticides and herbicides. The Pesticide Industry Sales and Usage 2006–2007 Market Estimates by the US EPA found that in 2007, the most common pesticide types on the US market were herbicides, insecticides, and fungicides, which is consistent with this study's findings.[36] Comparable information for occupational pesticide use is not available for Texas. A residential pesticide inventory in Texas found the most common pesticide ingredients were pyrethroids, which is supported by the EPA 2006–2007 market estimates; however, the inventory was limited to 2 counties in Texas and to residential pesticides and did not look at type of pesticide.[37] The most common exposure routes in this study were inhalation (49.1%), dermal (45.9%), and ingestion (15.2%). In 2015, the most common routes of exposure for all human exposures reported to the AAPCC were ingestion (79.6%), dermal (6.6%), and inhalation (6.0%).[3] Despite not being in the same order, the top 3 exposure routes were consistent between this study and all human exposures reported to the AAPCC. The present study had a higher percentage of exposures with inhalation and dermal compared to the AAPCC. This difference is most likely because the TPCN is a subset of the AAPCC data set and this study focused strictly on occupational pesticide poison center exposures. Common routes of exposure for pesticides depend on the occupation and task being performed. Damalas and Koutroubas (2016) found the most common exposure routes for farmworkers were dermal and inhalation, which is consistent with the present study.[38] Understanding routes of exposure can help to better educate employers and workers on preventive behaviors, including use of personal protective equipment (PPE).

The majority of exposures (88.3%) did not result in serious outcomes (eg, moderate effect, major effect, and death), with 45% of exposures managed on site. As a result, it might be expected that most of the exposures would not need to be managed at a health care facility. The most reported clinical effect categories were gastrointestinal (23.3%; $n = 712$), neurological (19.9%; $n = 610$), and dermal (13.9%; $n = 426$). The clinical effect categories are consistent with known literature on acute health effects, which include headaches, dizziness, nausea, diarrhea, vomiting, and skin problems.[6] Through understanding health effects, employers can better understand the risks to their employees, as well as plan for treatment of potential exposures.

This study did not find a clear temporal trend over the 16-year period. However, the number of occupational pesticide poison center exposures decreased overall from 2000 ($n = 168$) to 2015 ($n = 149$). Seasonally, the study found that a majority of exposures occurred during the spring and summer. Existing literature found seasonal differences most likely result due to pesticides being used more in the spring and summer.[37,39]

In 2016, Calvert and colleagues assessed occupational pesticide exposures using the SENSOR-pesticides program data for 2007–2011, which aggregated data for 12 states.[16] Calvert and colleagues identified 363 cases of acute occupational pesticide illness and injury in Texas.[16] Their case definition included information on pesticide exposures and adverse health effects that were confirmed.[16] For this same period (2007–2011), this present study identified 673 occupational pesticide poison center exposures that met the current study's case definition. The difference in cases and exposures is most likely due to a variation in case definition and differences in surveillance systems that are designed to capture different information. For example, SENSOR is the leading surveillance system to capture occupational pesticide exposures that defines *occupational pesticide injury or illness* as anyone that was exposed to 1 or more pesticides at the person's workplace. In addition, as noted in the preceding, most SENSOR-based publications only include confirmed cases whereas poison center data capture all reported exposures and are defined on generic code, exposure reason, and exposure site. Differences between SENSOR, poison center, and other surveillance systems (eg, hospitalization data) support the need to utilize multiple surveillance data sources to understand the potential burden of occupational pesticide exposures since there is no single national data set that captures all occupational pesticide exposures. Through the use of multiple surveillance systems, the burden of occupational pesticide exposures can be better understood. However, these data sources should be looked at individually or side by side unless linked data can be utilized because the same pesticide exposure can occur in multiple data sets, such as poison center, SENSOR, and hospitalization records.

There are limitations to utilizing poison center data to characterize occupational pesticide exposures. First, poison center data is voluntarily reported; thus, not all exposures are captured. Only pesticide exposures called into a poison center are known; there is no estimate for the number of pesticide exposures that are not reported.[3] Many cases of occupational pesticide exposure and illness may not be reported because the symptoms associated with pesticide exposure are not recognized or are misdiagnosed by health care providers.[16,17,40] An additional limitation is that the data are self-reported, which may potentially lead to bias. When addressing occupational exposures, poison center data are limited because neither dose information nor occupation (eg, industry and tasks being performed) is available. Another limitation of this article is the use of census data by age and gender that do not account for the number of individuals in these groups that are employed.

Despite these limitations, poison center data can be used to augment other data sources that capture occupational pesticide exposures. Poison center data provide information on exposure routes, medical outcomes, and clinical effects as well as gender and age differences. Despite not having information on occupation, the information obtained from this descriptive analysis can be utilized to inform various industries that commonly use pesticides (eg, farming, commercial agricultural). For example, Payne and colleagues found that high pesticide exposure events (HPEEs) were associated with modifiable behaviors that could reduce exposures through targeted safety training and education efforts.[41] Characterization of reported occupational exposures is beneficial in understanding pesticide exposures as well as identifying potential areas of concern, such as males having increased occupational pesticide exposures, insecticides being the most common pesticide, and differences in reported pesticide exposures by age. This general information can be used in the development of interventions targeting occupational pesticide exposures across multiple occupations as well as in the development of future research hypotheses to further explore the patterns identified in this article. A potential intervention for occupational groups that apply pesticides based on the findings of this study would be improved education efforts that present exposure trends. This information could be utilized to motivate individuals to use pesticides appropriately, including the use of PPE. In addition, through reviewing clinical effects and medical outcomes, this study provides information on the magnitude and types of health effects that have been observed with acute occupational pesticide exposures. Future research on occupational pesticide exposures is still needed to understand the burden, especially in Texas. It is also necessary to identify the causes (eg, risk factors, tasks performed) as well as their long-term health effects. It may be fruitful to explore data linkage as a means of helping to fill these gaps. In addition, future research could expand poison center data analysis to consider the association of multiple factors at the individual level, such as common clinical effects based on exposure route or clinical effects based on type of pesticide. Expanded analyses would prove to be beneficial in understanding occupational pesticide exposures and expected health effects, which could be used for educating health care providers on pesticide symptoms that may be misdiagnosed as other conditions.

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