Public Health Surveillance for the Prevention of Pesticide-Related Illness in Illinois

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Objectives: There is no pesticide related illness (PRI) surveillance program in Illinois. This study examines the quality of state-based data sources for their ability to inform public health surveillance on PRI. **Methods:** We estimated the counts of PRI by probabilistic data linkage of hospital discharge, emergency department, and poison center databases from 2010 to 2015. We characterized identified PRI cases. **Results:** We identified 3867 unique cases of PRI and 6269 asymptomatic pesticide exposures. Out of the 3867 PRI cases, there were 1319 emergency department visits and 321 hospitalizations. We identified 13 deaths and 1640 major or moderate effects from PRI. Over half of ingestion related exposures occurred in children aged 0 to 4 years. Workers' compensation and Emergency Medical Service data were unusable. **Conclusion:** An effective public health surveillance on PRI requires reliable state data sources and cost-effective methods of assembling data from multiple sources.

Keywords: data linkage, pesticide related illness, prevention, public health surveillance

INTRODUCTION

Pesticides are substances or mixtures of substances intended for preventing, destroying, repelling, or mitigating pests such as insects, mice and small animals, weeds, and fungi. They also serve as plant regulators, defoliants, desiccants, and nitrogen stabilizers.[1] These agents are deliberately released into the environment for a variety of purposes in both agricultural, recreational, and domestic applications.[2] Conventional pesticide types include herbicides, fungicides, insecticides, and fumigants.[3]

Pesticides are applied to farms and yards, as well as public spaces like schools, parks, office buildings and homes—so-called structural pesticide use—to destroy pests and/or inhibit their activities. It is estimated that about 90% of all households in the United States use pesticides.[4] There are over 20,000 pesticide products on the market in the United States, and about 1.1 billion pounds of active ingredients are used each year in the country.[5] Between 2005 and 2012, about 90% of pesticide usage in the United States was for agricultural purposes, with the remaining being for industry, commercial, government, home, and garden uses.[6] The use of pesticides has yielded significant benefits to both agriculture and public health, including pest control and increased food security.[7]

Pesticide Related Illness

Despite their benefits, exposure to pesticides can result in pesticide related illness (PRI), posing significant health challenges.[2] Acute PRI refers to ''any acute adverse health effect resulting from exposure to a pesticide product defined under the Federal Insecticide Fungicide and Rodenticide Act (FIFRA) including health effects due to an unpleasant odor, injury from explosion of a product, inhalation of smoke from a burning product, and allergic reaction.''[8]

From 2014 to 2016, exposure to pesticides was the ninth most frequent cause of calls to poison centers (PCs) across the United States, accounting for about 3% of exposures, and among the top 10 most frequent agents involved in poisoning in children under 5 years.[9,10] Pesticides were the third leading hazardous exposure to pregnant women in 2016, accounting for 527 cases (8.3%) of the 6338 pregnancy exposures from single substances.[9] In 2016, pesticides were the eighth most frequent substance involved in poisoning among adults over 20 years. Out of the 82,882 total pesticide-poisoning-related cases recorded by the PCs, there were 17 deaths, 102 major, 2128 moderate, and 13,585 minor health outcomes.[9]

Public Health Surveillance of Pesticide Related Illness

Due to the adverse health effects of pesticide exposure, it is essential to develop public health surveillance systems that efficiently monitor the trends and outcomes inform timely interventions for prevention of PRI. Although pesticide manufacturers perform premarket testing of pesticide products, not all harmful health effects occur during product use.[11] PRI surveillance systems are useful for identifying emerging pesticide related diseases, detecting outbreaks associated with new pesticides or new uses of long-used pesticides, and evaluating public health interventions to mitigate dose and adverse health effects.[12,13] Surveillance of PRI in the United States is conducted on a state-by-state basis, often by state agencies, sometimes with funding from the Federal government. The National Institute for Occupational Safety and Health (NIOSH) initiated the Sentinel Event Notification System for Occupational Risk (SENSOR) in 1987, covering PRI in addition to other occupational health disorders.[12] There are 12 states participating in SENSOR pesticides, reporting acute occupational PRI cases to NIOSH; 7 out of the 12 states report nonoccupational cases.[2]

Data sources used for PRI surveillance include reports from government agencies charged with addressing inadvertent exposures, use and misuse of pesticides such as state departments of agriculture and environmental protection agencies, as well as records from workers' compensation claims, poison control centers, death certificates, emergency medical services, hospital discharge, and emergency department (ED) visits.[11,12] Data on PRI can also be found on the Centers for Disease Control and Prevention's National

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Clinical significance: The hospital and Emergency department data provides invaluable information for PRI surveillance. Poison centers are a useful resource for clinicians when attending to suspected cases of PRI. Clinicians are encouraged to consult the poison centers during PRI encounters to help with diagnoses, management and surveillance efforts.

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Environmental Health Tracking Network website which obtains data from all states through the National Poison Data System. Since PCs capture data from individuals and health-care providers ^^that call on patients' behalf, they miss cases of people who die from an acute exposure, those who do not call the PC or seek medical attention, and from HCPs who manage cases without the assistance of PCs. Furthermore, it should be noted that the Environmental Health Tracking Network Web site (https://ephtracking.cdc.gov/DataExplorer/index.html?c =20&i=-1&m=-1#/) includes both pesticides and disinfectants and does not distinguish the two, limiting the ability to target interventions. As part of PRI surveillance efforts, 30 states in the United States require mandatory reporting of acute PRI from physicians, laboratory, or hospitals to state health departments.[11]

Gaps in Public Health Surveillance of Pesticide Related Illness

Both national and state surveillance data; SENSOR and non-SENSOR, underestimate the number of cases, and severity of illness; they also poorly characterize exposure scenarios and risks, diagnostic criteria medical interventions, and long-term health outcomes.[2,11,14,15] For example, the SENSOR-pesticides data system is unable to capture all the important pesticide exposure risk factors needed for prevention, and underestimates pesticide illnesses and exposures due to several challenges with the system[11]

Only the 12 SENSOR states in the United States use multiple data sources and do some degree of follow back for better characterization of the exposure event.[2] As of 2016, only 7 states out of the 12 participating states routinely reported cases from nonoccupational exposures to the SENSOR-pesticides program.[2] In a study by Mehler et al,[13] the California Pesticide Illness Surveillance Program did not capture majority of pesticide intoxications in the state, most of which were due to exposures at home. The authors identified the additional cases only after linking data across records from hospitals, death certificates, and the PCs. The National Academies of Sciences recommends the use of multiple state sources for effective surveillance.[16] Data linkage provides a useful means to integrate data across multiple sources, identify course of treatment, and better characterize the total number of unique incident cases.

Both agricultural and urban/structural use of pesticides is common in Illinois, the fifth largest state in the United States. Moreover, like most states, Illinois does not mandate or centralize PRI reporting. Illinois has maintained databases of a variety of health records including inpatient admissions, outpatient ED visits, emergency medical services runs (ambulance), PC calls, and other sources. The aims of this research were to explore the quality of existing data sources for their ability to inform public health surveillance on PRI and to estimate and characterize PRI through probabilistic data linkage of cases in usable data sources.

METHODS

Data Sources

We explored multiple data sources in Illinois to examine the potential for extraction of PRI cases. We obtained and examined five separate databases for included data elements and completeness of data entry, after which data linkage was used to connect cases across three systems: Hospital Discharge Data (inpatient cases), Emergency Department Data (outpatient emergency room visits), and the National Pesticide Data System (NPDS) database for Illinois (PC calls). NPDS is the repository for case reports from the Illinois poison center (IPC) (and from other US states). We extracted data on PRI for the period 2010 to 2015. We determined the numbers, rates, trends, and characteristics of PRI from the linked dataset. The fourth dataset we examined was the Illinois Workers' Compensation Commission administrative court records; however, these records yielded no cases for the years 2010 to 2015. The fifth dataset evaluated, Emergency Medical Services (ambulance run) database, was missing the "cause of injury/illness" for about 90% of the cases and no other variables captured pesticide exposure or illness, so we were unable to use it as a data source. Since hospital discharge (HD), ED, and PC databases allowed us to extract PRI cases by diagnosis codes, we used these sources for the study.

Hospital Discharge and Emergency Department Data

Illinois Hospital Discharge and Emergency Department (HDED) records are collected in a single database and maintained by the Illinois Hospital Association through the COMPdata informatics system. Patients who spend less than 24 hours in the hospital are classified as "outpatient" (ED) cases. Inpatients are patients who were treated for more than a 24-hour length of stay. In contrast to trauma registry data, these datasets capture information about patients treated in facilities without specialized trauma teams, as well as all outpatient cases. The outpatient database includes patients treated in emergency rooms for less than 24 hours who were not admitted to the hospital. The inpatient database includes patients treated for 24 hours or more. Based on the annual state audit of hospitals, the cases included in the datasets comprise 96.5% of all patient admissions statewide.[17]

Both datasets contain information on patient demographics, exposure information, health outcomes, and economic outcomes. The variables in the combined database include the hospital name (hospital identifier), patient demographic details (age, date of birth, sex, residence zip code of patient residence, race, ethnicity), date of admission, type of admission, date of discharge, payer source, hospital billing charges, International Classification of Diseases, Ninth Revision (ICD-9)-codes for nature and cause of injury (E-codes—mechanism), length of stay, and patient discharge status. This data source was separated into ED and hospitalization components in order to examine case differences between settings with differential acuity. The hospital discharge and ED data did not include records for the last quarter of 2015 because disease classification in the United States had transitioned from ICD-9 to the ICD-10 version. We extracted and analyzed data through 2015, because complete data were available for this period.

The National Poison Data System

The IPC data is a compilation of all the calls received by IPC staff. In addition to receiving calls from the general public, the IPC provides telephonic consultations to 190 facilities with emergency room services through a hospital membership network. Each hospital in the network pays a variable fee, which is based on the number of emergency room visits for all reasons (not restricted to poisoning visits) during the previous year. On average, the IPC receives 56 calls per year from each health-care facility (HCF) relating to inpatient cases (interquartile range 18 to 99 calls per year). IPC involvement is generally restricted to phone consultations, although bedside consults (about 250 per year) and real-time consults (about1200 per year) do occur. The IPC database contains cases for which calls were received for assistance in evaluating and managing poison exposures. The variables in the database include case number, date, age, gender, zip code, center code, call type, reason, exposure site, call site, call date, species type, HCF code, management site, level of HCF care, medical outcome, route of exposure, clinical effect, substance, ICD-9 diagnosis, and severity. Like other PCs, IPC uploads its data to the National Poisoning Data System, which maintains and publishes annual reports for the United States.[18] The variables: type of admission, patient discharge status, medical outcome call type, reason, and management site have been defined (supplementary material Table 5, http://links.lww.com/JOM/A713).

INCLUSION CRITERIA FOR CASES IN THE DATABASES

Pesticide Categories

We categorized illnesses resulting from pesticide exposures according to the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) diagnosis codes. ICD-9 was used in order to get longitudinal data, since ICD-10 has only been used for the last few years. We did not include data from the last quarter of 2015 for cases in the hospital discharge and ED data, because disease classification in the United States was being changed from ICD-9 to ICD-10. Since we extracted data based on ICD-9 classification in the previous years (2010 to 2014), we restricted PRI cases in 2015 to those with the ICD-9 format. The ICD-9 N code describes the specific chemical class of pesticides (and other agents). The ICD-9 External Cause of Injury codes (E-codes) were used to obtain information on intent, (unintentional, accidental, or intentional) and place of exposure occurrence. The codes used to extract health records of the PRI cases are listed in Table 1. We focused on conventional pesticides—herbicides, insecticides, fumigants and fungicides—which are legislated through the Federal Insecticide, Fungicide, Rodenticide Act (EPA 2016). Although disinfectants are also covered under FIFRA, we excluded them in this study because of their widespread use for cleaning and elimination of microbial hazards, rather than the narrower scope of agents that control insects, weeds, fungi, and rodents. Additionally, health-care providers are generally unfamiliar with FIFRA and are not likely to classify disinfectant poisoning as pesticide poisoning as pertains under the FIFRA.

TABLE 1. ICD-9-CM Codes and E-Codes Used for Extraction of Pesticide-Related Illnesses from the Hospital Discharge and Emergency Department Dataset, Illinois, 2010 to 2015

Code	Code Definition
989.0	Toxic effect of hydrocyanic acid and cyanides
989.1	Toxic effect of strychnine and salts
989.2	Toxic effect of chlorinated hydrocarbons
989.3	Toxic effect of organophosphate and carbamate
989.4	Toxic effect of other pesticides, not elsewhere classified.
E863.0	Accidental poisoning by insecticides of organochlorine compounds
E863.1	Accidental poisoning by insecticides of organophosphorus compounds
E863.2	Accidental poisoning by carbamates
E863.3	Accidental poisoning by mixtures of insecticides
E863.4	Accidental poisoning by other and unspecified insecticides
E863.5	Accidental poisoning by herbicides
E863.6	Accidental poisoning by fungicides
E863.7	Accidental poisoning by rodenticides
E863.8	Accidental poisoning by fumigants
E863.9	Accidental poisoning by other and unspecified agricultural and horticultural chemical and pharmaceutical preparations other than plant foods and fertilizers
E980.7	Poisoning by agricultural and horticultural chemical and pharmaceutical preparations other than plant foods and fertilizers, undetermined whether accidentally or purposely inflicted

E-code, external cause of injury or poisoning code; ICD-9-CM, International Classification of Diseases, Ninth Revision, Clinical Modification.

Hospital Discharge and Emergency Department Dataset

We identified cases of PRI in the hospital discharge and ED databases, through screening of the ICD-9 N-codes (nature of disease codes) and E-codes (cause of injury codes) which are presented in Table 1.

Illinois Poison center Dataset

We extracted the IPC's cases of PRI from the NPDS which is maintained by the American Association of Poison Control Centers (AAPCC) using the following extraction criteria; year (2010 to 2015), state of exposure (Illinois), estimated age (all), call type (exposure only), reason (unintentional and intentional exposure), and generic code indicator containing at least one of the AAPCC's general code categories that corresponds to pesticides[18,19] (supplementary material Table 4, http://links.lww.com/JOM/A714). The criterion for inclusion was any inquiry made to the IPC for an exposure to a pesticide. Cases of PRI were identified based on the above criteria, denoting exposure to substances with the appropriate generic codes for pesticides. We included ''exposure only'' call types from the dataset and excluded calls that sought only information about pesticides (without exposures) because most calls made to the PCs are only to seek information about exposures.

Case Extraction and Linkage

The IPC cases were first extracted from the NPDS for both pesticides and disinfectants, a joint category in NPDS. The IPC database has a variable ''management site,'' which identifies where the exposed person was managed or whether the IPC referred the person to a HCF when they received the call. Data elements for the variable ''management site'' for the cases extracted were either ''managed on site (non-HCF)'' or ''patient was referred by PCC to a HCF'' or ''patient already enroute to HCF when PCC was called (HCF-related).'' Based on the ''management site,'' we classified cases in the IPC as either PRI cases (HCF-related) or asymptomatic pesticide exposed individuals (non-HCF-related). Pesticide-related illness cases were those with the description ''patient already enroute to HCF when PCC called'' or ''patient was referred by PCC to an HCF.'' Asymptomatic pesticide exposed individuals were those with the description ''managed on site (non-HCF).''

We identified disinfectants per the E-code 861.4 (Accidental poisoning by disinfectants) and excluded these cases from both descriptive and data linkage analyses. Subsequently, only PRI cases were used for the data linkage and analyses. If a case was designated as non-HCF, we assumed that they were cases of possible (concern about) pesticide exposure, which did not manifest symptoms requiring medical intervention. These were excluded from the data linkage analyses.

We used a probabilistic linkage methodology to connect the cases of PRI in the PC with HDED datasets through multiple steps. The first pass identified records in the hospital discharge and ED and PC datasets that matched exactly on eight variables: hospital identification numbers, case number, patient age, sex, date of admission, date of call, type of exposure, and zip code. In the subsequent passes, variations in call date/admission date and age were inserted to test the linkage method for determining ''same'' cases in two different datasets. The last step involved linking the datasets to match exactly on hospital identification number, patient sex, patient age, date of admission/call date, without matching for exposure type between the records.

After each step of linkage, matched cases were combined into single cases, and duplicates were eliminated. The final dataset is a merge of all the linked cases (de-duplicated), along with cases that do not link. Data elements from each of the databases were retained in a large dataset to be used for a descriptive analysis of PRI cases in

Illinois. We used SAS software for all statistical analyses (v.9.4; SAS Institute Inc., Cary, NC, USA).

RESULTS

Numbers, Rates and Trends of PRI

Overall, we identified 3867 unique PRI cases and 6269 asymptomatic pesticide exposures in Illinois from 2010 to 2015 (Fig. 1 and Table 2). Out of the 3867 PRI cases, we identified 1319 cases in the ED data and 321 cases from the hospital discharge data. We identified 3065 PRI cases and 6269 asymptomatic pesticide exposed individuals from the PC data. Out of the 3065 PRI cases from the PC, 692 linked with the ED data, 99 linked with hospital discharge data, and 17 cases linked across all three databases. We assumed that the PC PRI cases which did not link with cases in ED or hospital discharge data ($n = 2291$) were cases that never went to a HCF when referred by the PC or were referred to HCFs that do not participate in the COMPdata system, private physician offices, urgent care facilities or other facilities without EDs. The lowest number of PRI cases was identified in hospital inpatient data ($N = 321$). Overall, 3867 unique PRI cases were managed at HCFs (Fig. 1).

Figure 2 shows number of asymptomatic pesticide-exposed and PRI cases, by data source, by year. Overall, both PRI and asymptomatic pesticide exposures decreased over the years, from 2010 to 2015 (Fig. 2). The trend of cases reporting to the PC declined steadily from 1741 cases in 2010 to 1481 cases in 2015. The trend of PRI cases reporting to the PC which were managed by HCFs followed a similar pattern of general decline, except the number of cases peaked in 2013, after which it declined. Unlike the trend of cases at the PC, PRI cases managed at the EDs and hospitals increased steadily, peaking in 2013, after which cases declined.

Table 2 is a comprehensive display of data elements by the databases they are used in, as well as the numbers and proportions of PRI cases and asymptomatic pesticide exposed individuals by pesticide category, from each data source. In terms of demographics, all databases contain age and gender, but unlike the hospital discharge and ED data, the PC data does not query race or ethnicity. All sources allow case extraction by diagnosis: an ICD-9 N code for diagnosis (of PRI) and ICD-9E codes are contained in the hospital discharge and ED database, with the equivalent data field of ‘‘reason for exposure’’ in the PC database. The PC captures the location where poisoning occurred (‘‘site of exposure’’) and the route of exposure (‘‘route’’), while the other data sources do not. This information is critical in guiding interventions. Finally, a surrogate for ‘‘severity of injury’’ can be assembled from each of the three sources through the fields ‘‘medical outcomes’’ (PC), discharge status (hospital discharge and ED) and length of stay (hospital discharge).

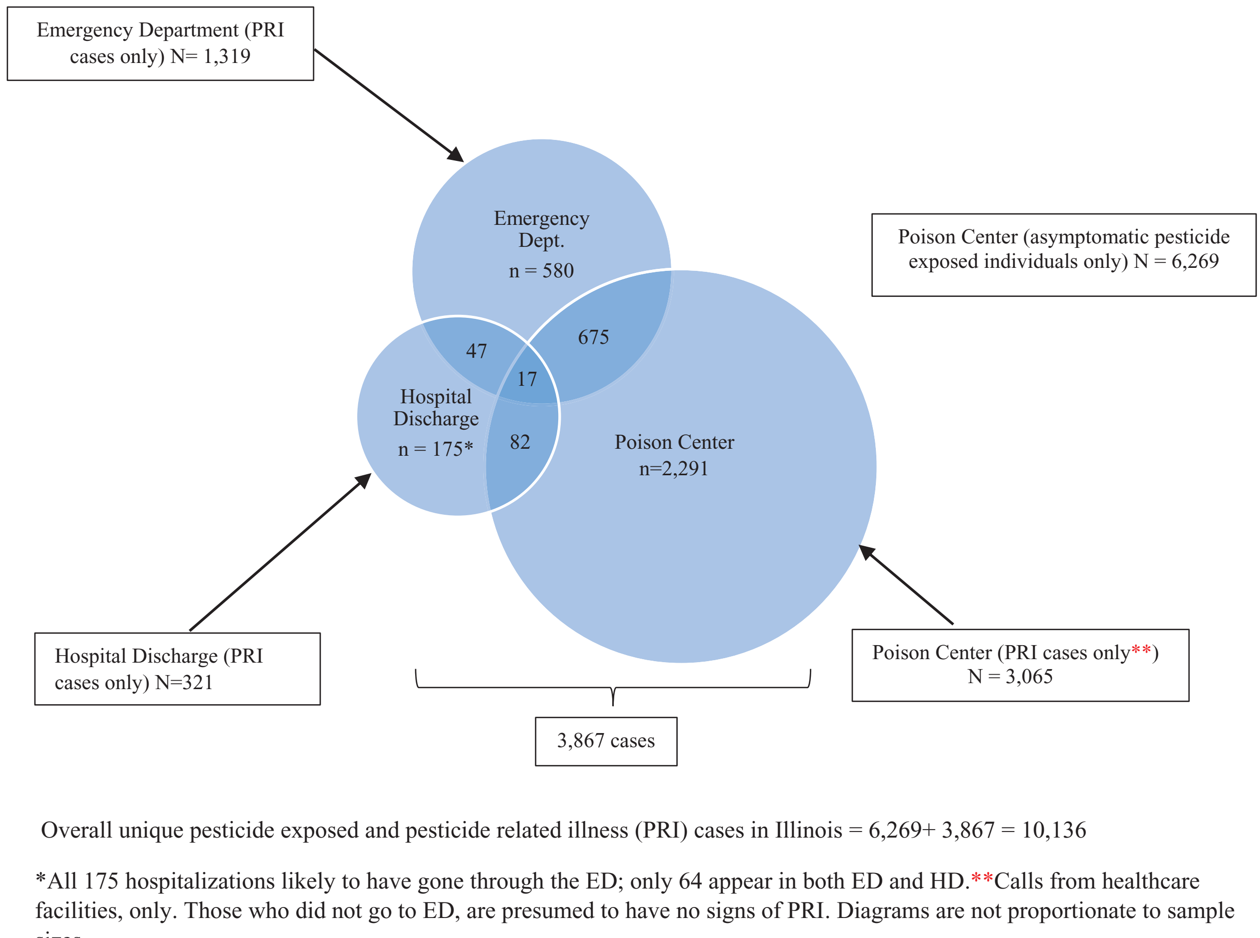

FIGURE 1. Number of pesticide exposed and pesticide related illnesses in Illinois by data source from poison center, emergency department, and hospital discharge, 2010 to 2015. ED, emergency department; HD, hospital discharge; PC, poison center.

TABLE 2. Distribution of Pesticide Exposed, and Pesticide-Related Illness Cases Identified from PC, ED, and Hospital Discharge Data, Illinois, 2010 to 2015

	Poison Center (PRI) $n = 3{,}065$			Emergency Department (PRI) $n = 1{,}319$			Hospital Discharge (PRI) $n = 321$			Pesticide Exposed Individuals (Asymptomatic) $n = 6{,}269$		
Characteristic	Chlorinated Hydrocarbons $N = 19$ n (%)	Organophosphates and Carbamates $N = 170$ N (%)	Other Pesticides, Not Elsewhere Classified $N = 2{,}876$ n (%)	Chlorinated Hydrocarbons $N = 20$ n (%)	Organophosphates and Carbamates $N = 35$ n (%)	Other Pesticides Not Elsewhere Classified $N = 1{,}264$ N (%)	Chlorinated Hydrocarbons $N = 17$ N (%)	Organophosphates and Carbamates $N = 13$ n (%)	Other Pesticides Not Elsewhere Classified, $N = 291$ n (%)	Chlorinated Hydrocarbons $N = 24$ n (%)	Organophosphates and Carbamates $N = 259$ n (%)	Other Pesticides, Not Elsewhere Classified $N = 5{,}986$ n (%)
Gender												
Female	8 (42.1)	68 (40.0)	1,256 (43.7)	8 (40.0)	9 (25.7)	583 (46.1)	5 (29.4)	3 (23.1)	111 (38.1)	13 (54)	121 (46.7)	2,844 (47.5)
Male	11 (57.9)	102 (60.0)	1,568 (54.5)	12 (60.0)	26 (74.3)	681 (53.9)	12 (70.6)	10 (76.9)	177 (60.8)	11 (20.3)	134 (51.7)	3,089 (54.7)
Unknown	0 (0)	0 (0)	52 (1.8)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	3 (1.0)	1 (4.9)	4 (8.6)	52 (0.9)
Age												
0–4	7 (36.8)	25 (14.7)	1,134 (39.4)	4 (20)	6 (17.1)	564 (44.6)	0 (0)	0 (0)	7 (2.4)	8 (33.3)	170 (65.6)	4,823 (80.6)
5–9	0 (0)	6 (3.5)	135 (4.7)	1 (5)	3 (8.6)	38 (3.0)	0 (0)	1 (7.7)	0 (0)	3 (12.5)	33 (12.7)	566 (9.5)
10–15	0 (0)	7 (4.1)	58 (2.0)	1 (5)	4 (11.4)	26 (2.1)	0 (0)	1 (7.7)	6 (2.1)	0 (0.0)	5 (1.9)	67 (1.1)
16–24	2 (10.5)	21 (12.4)	247 (8.6)	1 (5)	2 (5.7)	107 (8.5)	0 (0)	0 (0)	34 (11.7)	0 (0.0)	32 (12.4)	312 (5.2)
25–34	1 (5.3)	16 (9.4)	199 (6.9)	3 (15)	5 (14.3)	136 (10.8)	1 (5.9)	0 (0)	44 (15.3)	0 (0.0)	1 (0.4)	16 (0.3)
35–44	5 (26.3)	16 (9.4)	190 (6.6)	2 (10)	6 (17.1)	143 (11.3)	1 (5.9)	1 (7.7)	59 (20.5)	0 (0.0)	4 (1.5)	9 (0.2)
45–55	1 (5.3)	27 (15.9)	269 (9.4)	2 (10)	3 (8.6)	107 (8.5)	0 (0)	2 (15.4)	64 (22.2)	0 (0.0)	0 (0.0)	6 (0.1)
56–65	1 (5.3)	17 (10.0)	157 (5.5)	1 (5)	3 (8.6)	67 (5.3)	6 (35.3)	2 (15.4)	40 (13.9)	0 (0.0)	2 (0.8)	5 (0.1)
Above 65	2 (10.5)	25 (14.7)	192 (6.7)	5 (25)	3 (8.6)	76 (6.0)	9 (52.9)	6 (46.2)	34 (11.8)	0 (0.0)	0 (0.0)	4 (0.1)
Age												
Unknown	0 (0)	10 (5.9)	295 (10.3)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	4 (16.7)	12 (4.6)	178 (3.0)
Race												
Indian or Alaska Native	N/A	N/A	N/A	1 (5)	0 (0)	4 (0.3)	0 (0)	0 (0)	1 (0.3)	N/A	N/A	N/A
Asian	N/A	N/A	N/A	0 (0)	0 (0)	7 (0.6)	0 (0)	0 (0)	4 (1.4)	N/A	N/A	N/A
Black or African American	N/A	N/A	N/A	1 (5.0)	8 (22.9)	433 (34.3)	2 (11.8)	3 (23.1)	97 (33.3)	N/A	N/A	N/A
Native Hawaiian or Pacific Islander	N/A	N/A	N/A	0 (0)	0 (0)	4 (0.3)	0 (0)	0 (0)	1 (0.3)	N/A	N/A	N/A
White	N/A	N/A	N/A	14 (70.0)	22 (62.9)	594 (47.0)	15 (88.2)	8 (61.5)	150 (51.5)	N/A	N/A	N/A
Other	N/A	N/A	N/A	4 (20.0)	5 (14.3)	222 (17.6)	0 (0)	2 (15.4)	38 (13.1)	N/A	N/A	N/A
Unknown	N/A	N/A	N/A	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	N/A	N/A	N/A
Ethnicity												
Hispanic/Latino	N/A	N/A	N/A	5 (25)	1 (2.9)	184 (14.6)	0 (0)	1 (7.7)	32 (11.0)	N/A	N/A	N/A
Non-Hispanic /Non-Latino	N/A	N/A	N/A	15 (75)	34 (97.1)	1,337 (86.1)	17 (100)	12 (92.3)	256 (88.0)	N/A	N/A	N/A
Unknown	N/A	N/A	N/A	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	N/A	N/A	N/A
Reason for exposures												
Intentional	3 (15.8)	22 (12.9)	308 (10.7)	(0)	0 (0)	62 (4.9)	0 (0)	3 (23.1)	114 (39.6)	2 (8.3)	3 (1.1)	43 (0.7)
Unintentional	16 (84.2)	148 (87.1)	2,511 (87.3)	7 (35.0)	16 (45.7)	1,005 (79.5)	4 (23.5)	10 (76.9)	128 (44.4)	22 (91.6)	256 (98.8)	5,943 (99.2)
Unknown	0 (0)	0 (0)	57 (2.0)	13 (65.0)	19 (54.3)	259 (20.5)	13 (76.5)	0 (0)	46 (16.0)	0 (0.0)	0 (0.0)	0 (0.0)
Route of exposure												
Dermal	1 (5.3)	26 (15.3)	245 (8.5)	N/A	N/A	N/A	N/A	N/A	N/A	4 (16)	42 (16.2)	556 (9.3)
Ingestion	6 (31.6)	49 (28.8)	1,462 (50.8)	N/A	N/A	N/A	N/A	N/A	N/A	10 (40.0)	132 (51.0)	4,180 (69.8)
Inhalation	8 (42.1)	35 (20.6)	467 (16.2)	N/A	N/A	N/A	N/A	N/A	N/A	3 (12)	24 (9.3)	219 (3.7)
Ocular	0 (0)	19 (11.2)	261 (9.1)	N/A	N/A	N/A	N/A	N/A	N/A	3 (12)	12 (4.6)	378 (6.3)
Multiple	4 (21.1)	30 (17.6)	380 (13.2)	N/A	N/A	N/A	N/A	N/A	N/A	4 (16)	47 (18.1)	620 (10.4)
Other	0 (0)	0 (0)	13 (0.5)	N/A	N/A	N/A	N/A	N/A	N/A	4 (16)	42 (16.2)	556 (9.3)
Route of exposure												
Unknown	0 (0)	11 (6.5)	48 (1.7)	N/A	N/A	N/A	N/A	N/A	N/A	1 (4)	2 (0.8)	33 (0.6)
Site of exposure												
Residence	14 (73.7)	152 (89.4)	2,709 (94.2)	N/A	N/A	N/A	N/A	N/A	N/A	24 (96)	258 (99.6)	5,922 (98.9)
Public area	1 (5.3)	0 (0)	7 (0.2)	N/A	N/A	N/A	N/A	N/A	N/A	0 (0)	0 (0)	41 (0.7)
School	2 (10.5)	2 (1.2)	5 (0.2)	N/A	N/A	N/A	N/A	N/A	N/A	1 (1.9)	0 (0)	6 (0.1)
Workplace	1 (5.3)	16 (9.4)	149 (5.2)	N/A	N/A	N/A	N/A	N/A	N/A	0 (0)	0 (0)	15 (0.3)
Other	1 (5.3)	0 (0)	2 (0.1)	N/A	N/A	N/A	N/A	N/A	N/A	0 (0)	0 (0)	2 (0.0)
Unknown	0 (0)	0 (0)	4 (0.1)	N/A	N/A	N/A	N/A	N/A	N/A	24 (96)	258 (99.6)	5,922 (98.9)
Severity												
Death	0 (0)	1 (0.6)	2 (0.1)	0 (0)	1 (2.9)	4 (0.3)	0 (0)	3 (23.0)	2 (0.7)	0 (0)	0 (0.0)	0 (0.0)
Mean length of stay. Days (sd)	N/A	N/A	N/A	N/A	N/A	N/A	2.3 (3.5)	1 (1.4)	0.7 (6.3)	N/A	N/A	N/A

TABLE 2. (Continued)

Characteristic	Poison Center (PRI) n = 3,065 Chlorinated Hydrocarbons N = 19 n (%)	Poison Center Organophosphates and Carbamates N = 170 N (%)	Poison Center Other Pesticides, Not Elsewhere Classified N = 2,876 n (%)	Emergency Department (PRI) n = 1,319 Chlorinated Hydrocarbons N = 20 n (%)	Emergency Department Organophosphates and Carbamates N = 35 n (%)	Emergency Department Other Pesticides Not Elsewhere Classified N = 1,264 N (%)	Hospital Discharge (PRI) n = 321 Chlorinated Hydrocarbons N = 17 N (%)	Hospital Discharge Organophosphates and Carbamates N = 13 n (%)	Hospital Discharge Other Pesticides Not Elsewhere Classified, N = 291 n (%)	Pesticide Exposed Individuals (Asymptomatic) n = 6,269 Chlorinated Hydrocarbons N = 24 n (%)	Pesticide Exposed Organophosphates and Carbamates N = 259 n (%)	Pesticide Exposed Other Pesticides, Not Elsewhere Classified N = 5,986 n (%)
Severity												
Discharge home	N/A	N/A	N/A	19 (95.0)	33 (94.3)	1,198 (94.8)	9 (52.9)	5 (38.5)	160 (55.0)	N/A	N/A	N/A
Discharge/Transferred to a facility	N/A	N/A	N/A	1 (5.0)	1 (2.9)	46 (3.6)	8 (47.1)	5 (38.5)	104 (35.7)	N/A	N/A	N/A
No effect	7 (36.8)	21 (12.4)	428 (14.9)	N/A	N/A	N/A	N/A	N/A	N/A	5 (20)	58 (22.4)	2,540 (42.4)
Minor	8 (42.1)	70 (41.2)	1,057 (36.8)	N/A	N/A	N/A	N/A	N/A	N/A	20 (80)	201 (77.6)	3,436 (57.4)
Moderate	0 (0)	23 (13.5)	280 (9.7)	N/A	N/A	N/A	N/A	N/A	N/A	0 (0)	0 (0)	8 (0.1)
Major	0 (0)	1 (0.6)	8 (0.3)	N/A	N/A	N/A	N/A	N/A	N/A	0 (0)	0 (0)	1 (0.0)
Other*	4 (21.8)	54 (31.8)	1,101 (38.3)	0	0	16 (1.3)	0	0	25 (8.6)	5 (20)	58 (22.4)	2,540 (42.4)

ED, emergency department; HD, hospital discharge; PC, poison center, PRI, pesticide-related illness.
*Other for PC, are cases not followed yet deemed potentially toxic exposures, cases where the exposure was probably not responsible for the effect (s), not followed, judged as nontoxic exposures (clinical effects not expected) and confirmed nonexposures. *Other for emergency and hospital discharge, are cases that left Against Medical Advice or referred to other facilities and hospices.

Demography of Pesticide Exposed and PRI Cases

Males were more highly represented among PRI cases in all three databases and the combined database, and across all pesticide types (Table 2). Race and ethnicity were not captured in the PC database, but among ED visits and hospitalizations, African Americans were more highly represented than their proportion in Illinois (32.4 vs 14.6). Children aged under 16 years represented 71.7% of the cases in the merged dataset, including the PC cases that were not from a HCF; there were 1327 cases (43.3%) and 647 cases (49.1%) in the PC and ED data, respectively, but only 15 cases (4.7%) in the hospital discharge data. In this age group, there were no hospital admissions for exposures to chlorinated hydrocarbons though they had reported to the PC and EDs with such exposures. Admissions for organophosphates and carbamates and "other pesticides" were relatively low compared to cases presenting to the PC.

Table 3 shows the distribution of the overall number of PRI cases and asymptomatic pesticide exposures (10,136). These are unique asymptomatic pesticide exposure which did not require medical intervention, and PRI cases (de-duplicated) that were either referred to HCFs by the PC, already at HCFs when a call was placed to the PC or managed directly at HCFs without calling the PC.

Intentionality of Pesticide Exposures

We do not have "intention" of exposures in any but the PC data. The variable "reason" provided information on the intention of exposures; in the PC dataset 2416/3065 (78.8%) of cases were unintentional, 294 (9.6%) were intentional and 355 (11.6%) were unknown for this category. In people aged under 20, there were 39/294 (13%) intentionally poisoned through ingestion (31 cases) and other routes of exposure, unspecified (eight cases). About 99.2% (1323 cases) of unintentional exposures among those aged under 20 occurred through ingestion. Most unintentional exposures in people aged 20 and above occurred through the noningestion route (861 cases, 83.1%). Out of the PC cases referred to HCFs, 333/3065 (10.9%) were intentional and 2675/3065 (87.3%) were unintentional exposures. The referred PC cases that linked with hospitalization data consisted of 62/99 (62.3%) intentional exposures and 34/99 (34.3%) unintentional exposures.

The PC data provided a more comprehensive information on the intention of exposures for PRI cases compared to the hospital discharge and ED data, the PC data missed on only 2.0% of PRI cases from "other pesticides" category. The ED and hospital discharge data however, missed a higher proportion of information on the intention of exposures. The hospital discharge data missed information on about 76.5% of chlorinated hydrocarbon exposures, while the ED data missed about 54.3% of organophosphates and carbamate exposures. The intentionality or reason of exposures for cases in the hospital and emergency discharge data were determined from their ICD-9 E-codes.

Pesticide Types Involved in Exposures

Among the 10,136 cases of PRI and pesticide (nondisinfectant) exposures that resulted in calls to the PC, ED visits, and/or hospitalizations, there were three categories of cases based on their ICD-9 N code classifications. These were "toxic effect of organophosphate and carbamate" (ICD code 989.3), "toxic effects of chlorinated hydrocarbons" (ICD code 989.2), and "toxic effect of other pesticides," not elsewhere classified (ICD code 989.4). There were 443 organophosphate poisoning cases (4.3% of total pesticide poisonings); 78 chlorinated hydrocarbon cases (0.8% of total pesticide poisonings); and 9615 cases of "other pesticide" exposures (94.9% of total pesticide poisonings). Pesticides in the "other pesticides" category were rodenticides (35.3%), insecticides (30.9%), herbicides (5.7%), fungicides (2.8%), fumigants (0.1%), and other unspecified pesticides (25.2%). The PC contributed most cases in all three categories (Table 2).

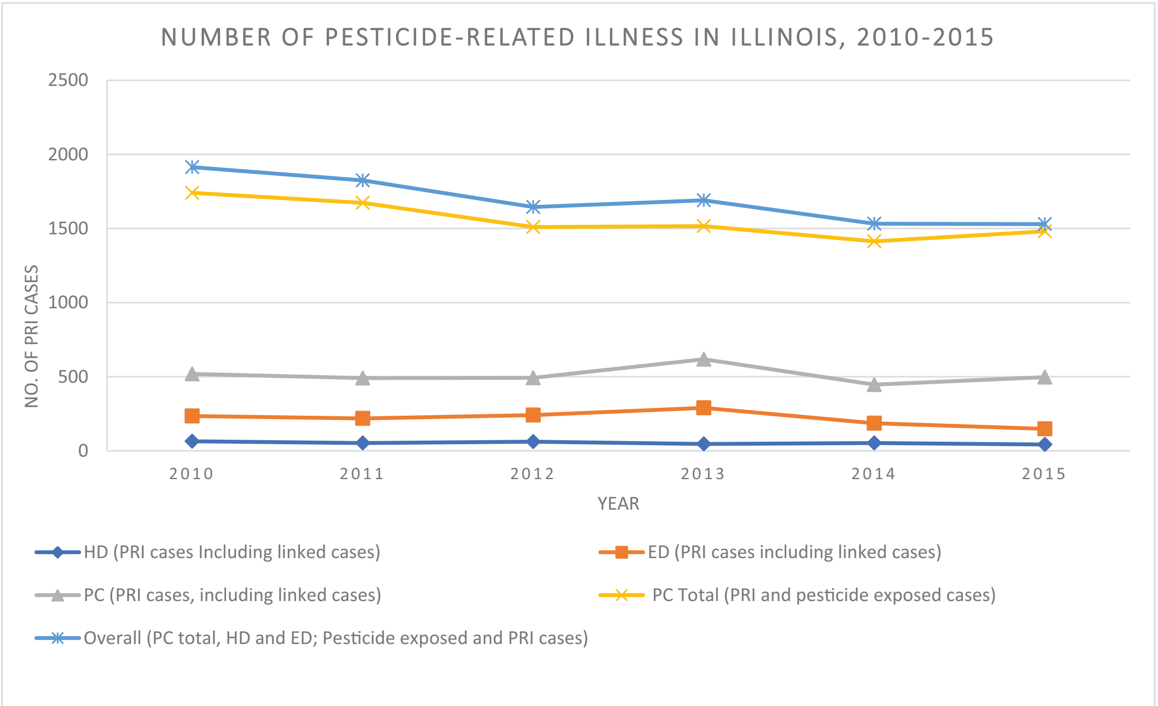

FIGURE 2. Trend of pesticide exposed and pesticide-related illness cases, by data source poison center and hospital discharge, and emergency department, and overall cases, Illinois, 2010 to 2015. ED, emergency department; HD, hospital discharge; PC, poison center.

Routes of Exposure and Site of Exposures

Ingestion is by far the most common route of entry of pesticides detected (available only in the IPC/NPDS data), with most cases in the ''other pesticides'' category (5090 cases) versus organophosphates and carbamates (169 cases). Inhalation was the most common route of exposures to chlorinated hydrocarbons (10 cases, 12.8%). Dermal and ocular route of exposure were only involved in 883 cases and 635 cases, respectively.

Residences were the most frequent sites of exposure for all pesticide categories. Workplace exposures were the second most frequent site of pesticide exposures. In term of routes of exposures by site, about 71.4% (5916 cases) of the exposures at residences occurred via ingestion, with 28.6% (2373 cases) through noningestion routes. Conversely, only 10.9% (16 cases) of the exposures at the workplace were through ingestion. Most of the exposures at the workplace were through the noningestion routes (89.1%, 131 cases), of which the major routes were inhalation (49.6%, 65 cases) and dermal absorption (36.6%, 48 cases).

Severity of Pesticide Exposed and PRI Cases

Most of the exposures resulted in minor to no effects. Out of the total 10,136 cases of pesticide exposed and PRI cases, 3867 cases (38.1%) were HCF related. These were cases either managed at HCFs directly, had referrals to HCFs when they called the PC, or were on their way to a health facility when they called the PC. The other 6269 cases were non-HCF related. These were asymptomatic pesticide exposed individuals without illnesses (Fig. 1). Overall, exposure to organophosphate and carbamates resulted in the highest severity of cases. It had the least routine home discharges (37 cases, 8.4%), highest mean length of hospital stay (6 ± 4.5 days) and the highest proportions of overall deaths (four cases, 0.9%). There was a total of 13 pesticide-related deaths (Table 3).

Figure 3 is a display of the pyramid of severity of PRI in Illinois. Severity of cases was displayed based on the required level of health care and death outcomes of all cases. They were classified as minor, moderate, major, and deaths. Minor cases were PC (HCF-only) cases which were neither found in the ED nor in HD data. We assumed that PRI cases from the PC which were HCF related yet were not identified in the HD or ED data were minor cases. The minor cases were those who might have had symptoms from pesticide exposure, but had their symptoms resolved without treatment.[2] They may have been referred to HCFs but never went to the facilities, or were referred to private physician offices, facilities without EDs, urgent care facilities, or HCFs that do not participate in the COMPdata system. Moderate and major cases were those that required ED visits and hospitalizations, respectively.

DISCUSSION

PRI is common, costly, and preventable.[20] Public health surveillance for PRI is fragmented across the United States, relying mainly on the limited information collected from PCs through the NPDS. A few states have funding from state governments and from NIOSH to conduct follow backs on reported cases and to engage in comprehensive intervention activities; however, the vast majority of states do not. Given the widespread use of pesticides in both urban and rural environments, the toxicity of the agents, and the fact that pesticide use is highly legislated by the federal and state governments, a more comprehensive and uniform approach is called for.

According to the National Academies of Sciences, state-based sources for public health surveillance have a high yield of information and use of secondary data is much less costly than an active system.[16] As demonstrated in this study, it is possible to get a more accurate count of cases and trends over time by using existing data sources; the use of hospital discharge and ED data for 2010 to

TABLE 3. Distribution of Unique Pesticide-Exposed and Pesticide-Related Illness Cases Identified from Poison Center, Emergency Department and Hospital Discharge Data, Linked and De-Duplicated, Illinois, 2010 to 2015

Characteristic	Chlorinated Hydrocarbons $N = 78$ n (%)	Organophosphates and Carbamates $N = 443$ n (%)	Other Pesticides, Not Elsewhere Classified $N = 9{,}615$ n (%)	Total, Merged Dataset $N = 10{,}136$
Gender				
Female	13 (54)	121 (46.7)	2,844 (47.5)	13 (54)
Male	11 (20.3)	134 (51.7)	3,089 (54.7)	11 (20.3)
Unknown	1 (4.9)	4 (8.6)	52 (0.9)	1 (4.9)
Age				
0–4	19 (24.4)	192 (43.3)	6,107 (63.5)	6,318 (62.8)
5–9	4 (5.1)	43 (9.7)	699 (7.3)	746 (7.4)
10–15	1 (1.3)	13 (2.9)	140 (1.5)	154 (1.5)
16–24	10 (12.8)	52 (11.7)	654 (6.8)	716 (7.1)
25–34	5 (6.4)	21 (4.7)	322 (3.3)	348 (3.4)
35–44	7 (9.0)	26 (5.9)	337 (3.9)	370 (3.7)
45–55	3 (3.8)	27 (6.1)	378 (3.9)	408 (4.0)
56–65	7 (9.0)	21 (4.7)	231 (2.4)	259 (2.6)
Above 65	16 (20.5)	28 (6.3)	276 (2.9)	320 (3.2)
Unknown	6 (7.7)	20 (4.5)	471 (4.9)	497 (4.9)
Ethnicity				
Hispanic /Latino	5 (6.4)	2 (0.5)	216 (2.3)	223 (2.2)
Non-Hispanic/Non-Latino	31 (39.7)	45 (10.2)	1,304 (13.6)	1,380 (13.6)
Unknown	42 (53.9)	396 (89.4)	8,095 (84.4)	8,533 (84.2)
Reason for exposures				
Intentional	24 (5.4)	625 (6.5)	652 (6.4)	24 (5.4)
Unintentional	373 (83)	7,785 (80.7)	8,167 (80.6)	373 (83)
Unknown	46 (10.3)	1,232 (12.8)	1,317 (13.0)	46 (10.3)
Route of exposure				
Dermal	5 (6.4)	68 (15.3)12	760 (7.9)	883 (8.2)
Ingestion	16 (20.5)	169 (38)	5,090 (52.9)	5,275 (52.0)
Inhalation	10 (12.8)	51 (11.5)	585 (6.1)	646 (6.4)
Ocular	3 (3.8)	29 (6.5)	603 (6.3)	635 (6.3)
Multiple	7 (9.0)	67 (15.1)	938 (9.8)	1,012 (10.0)
Other	0 (0)	0 (0)	16 (0.2)	16 (0.2)
Unknown	37 (47.4)	59 (13.3)	1,623 (16.9)	1,719 (17.0)
Site of exposure				
Residence	37 (47.4)	379 (85.6)	7,873 (81.9)	8,289 (81.8)
Public area	1 (1.3)	0 (0.0)	44 (0.5)	45 (0.4)
School	1 (1.3)	2 (0.5)	10 (0.1)	13 (0.1)
Workplace	1 (1.3)	15 (3.4)	131 (1.4)	147 (1.5)
Other	1 (1.3)	0 (0)	4 (0.0)	5 (0.0)
Unknown	37 (47.4)	47 (10.6)	1,553 (16.2)	1,637 (16.2)
Severity				
Death	0 (0)	4 (0.9)	9 (0.1)	13 (0.1)
Mean length of stay. Days (sd)	3.6 (1.5)	6.0 (4.5)	0.2 (11.5)	
Discharge Home	28 (35.9)	37 (8.4)	1,352 (14.1)	1,417 (14.0)
Discharge/ Transferred to a facility	8 (10.3)	6 (1.4)	155 (1.6)	169 (1.7)
No effect	8 (10.3)	31 (7.0)	670 (7.0)	709 (7.0)
Minor	16 (20.5)	200 (45.1)	3,998 (41.6)	4,214 (41.6)
Moderate	0 (0)	18 (4.1)	221 (2.3)	239 (2.4)
Major	0 (0)	0 (0)	7 (0.1)	7 (0.1)
Other*	18 (23.1)	147 (33.2)	3,203 (33.3)	3,369 (33.2)

Pesticide Surveillance for the Prevention of Pesticide-Related Illnesses in Illinois.

*poison center cases not followed yet deemed potentially toxic exposures, cases where the exposure was probably not responsible for the effect (s), not followed, judged as nontoxic exposures (clinical effects not expected) and confirmed nonexposures. Emergency and hospital discharge cases that left against medical advice or referred to other facilities and hospices.

2015 added an additional 802 cases to the 3065 NPDS cases, adding 26.1% to the total during that period. In addition to counts, data linkage allowed us to assemble a large dataset and with an array of data elements not present in each of the databases but capturing similar types of information. For example, severity could be determined by an assessment of the health effect (deaths, major, moderate, minor in the NPDS data; length of stay, proportion discharged home, proportion transferred to other facility and deaths in the HDED data). We assume that a case being referred to a facility is more severe than someone being discharged home. While we did not explore this in our study, it would also be possible to extract electronic medical records and get more detailed information such as exposure scenarios which could guide interventions.

In terms of other state data sources, the emergency medical service (EMS) database was unsuitable due to poor characterization and completeness of pesticide cases. Though the database usually has little missing data across most major variables, PRI cases were poorly captured. However, it is promising in terms of the other data

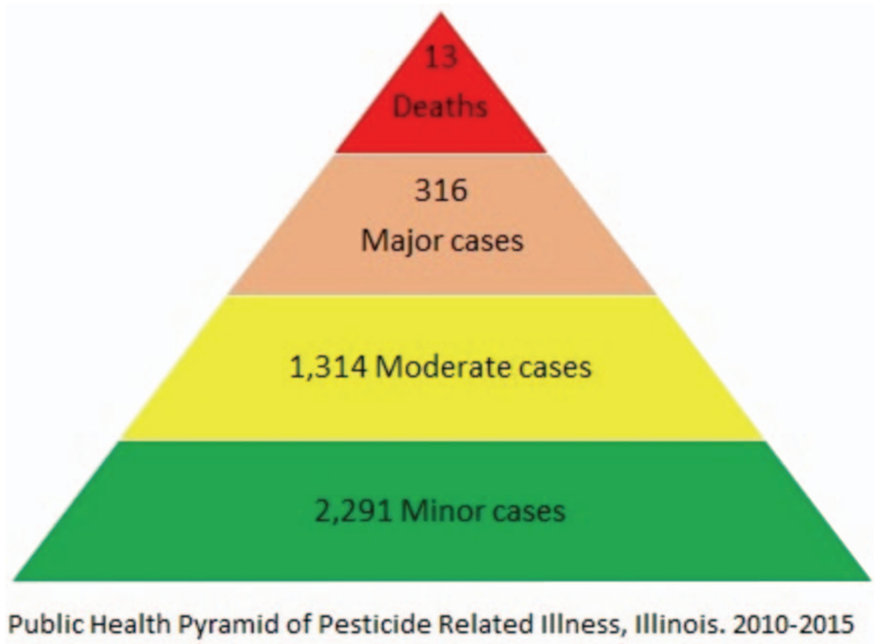

FIGURE 3. Public health pyramid of severity of pesticide related illness in Illinois, 2010 to 2015.

elements it queries. Through the National Emergency Medical Services Information System (nemsis.org), there is a uniform data collection system for ambulance runs across the United States. As more states sign onto this and data collection becomes more rigorous, this source could add a tremendous amount of information to our understanding of PRI, though data elements like ''suspected exposure'' might need to be added to obtain better information on pesticides and other poisons.

In a practical sense, surveillance for PRI depends on: recognition of the hazards and health effects by the public, including workers and employers (notably, there is an absence of cases from the workers' compensation system); reporting to a HCF or to the PC; recognition of PRI signs and symptoms on the part of health-care providers; and a comprehensive system that allows for data extraction from clinical data sources like hospitalizations, ED visits, and PC calls and also captures data from clinics and urgent care centers that may be encountering PRI cases. EMS data is becoming uniform across the United States and promoting the completion of data fields by EMS providers could add to the count. Only seven states have mandatory clinician reporting to a centralized place,[2] and even these are likely to have a significant undercount, given that reporting is not likely to be complete: clinicians have limited training in PRI recognition and management; even when they see cases, they may not report them. Finally, there are laws in all states that require state entities like the Environmental Protection Agency, Department of Agriculture, and Department of Natural Resources to receive calls and act on pesticide spills, drift, and other unintended exposures. These agencies could be connected with a comprehensive surveillance system to assure case capture, and also to directly instigate preventive action when preventable scenarios come to light.

Workers' compensation (WC) data yielded no cases for 2010 to 2015, though, logically, this would be an excellent source of work-related PRI. There are several probable reasons for the lack of cases: the threshold for reporting a case into most state WC systems is loss of work-time of greater than 3 to 7 days, and most PRI cases resolve earlier than that; WC laws often require employment by a single employer for a certain number of weeks before workers are eligible for WC insurance (in Illinois it is 14 weeks in agriculture); while they are at risk for pesticide exposure, migrant and seasonal farm workers often are not included in WC systems. Additionally, family owned farms are not required to buy WC insurance for family members working on farms. Finally, reporting in WC systems, in general, is patchy due to lack of knowledge of the system, lack of recognition of a disorder being work related on the part of health-care providers, and disincentives to report on the part of employers, workers, and clinicians.[14] It is important to note that use of secondary data and data linkage methods require a level of analytic skill that may not be available in health departments and could benefit by agreements with universities to conduct this type of analysis. Also, use of data sources across state agencies often requires data sharing agreements. More and more data repositories are being shared across the U.S., and this holds promise for PRI surveillance in the future.

Utilization of the IPC

The PC provides support for the management of poisoning cases for the public and health-care providers. However, utilization by health-care providers may be variable. From our study, some cases were managed by health-care providers without consultation with the IPC. At the ED, 580 cases (44.0%) of the 1319 cases were managed without consultation with the IPC. Among the hospitalized patients (hospital discharge), health-care providers managed 175 cases (54.5%) of the 321 cases without consulting the IPC. Over the last decade however, consultation to the IPC by health-care providers managing poisoned patients has increased by 37%. In 2018, 34% of the calls to the IPC for poisoning or overdose cases came from HCFs.[21] If a health-care provider at the point of care does not consult the IPC concerning a case, the IPC is unlikely to have records of the case, unless someone had called earlier on the patient's behalf. Though we identified some cases in the hospital discharge data which had no records in the ED data, it is likely that almost all hospital discharge cases went through an ED first, however some may have been admitted directly from physician's offices or had unknown or missing data on the variable ''type of admission.'' The admission type specifies whether patients were admitted from an emergency unit, urgent care, trauma center, or others (variable data dictionary in supplementary material).

Prevention of Pesticide Exposures

Most of the pesticide exposures in our study occurred at residences through ingestion. Regularly, homes have been a frequent site of poisonings. The 2016 annual report of the American AAPCC estimates that about 90.9% of all poisoning exposures occur at residences.[9] Because the home is a frequent site of pesticide exposure and children are at an increased risk of unintentional exposures through ingestion, there should be continuous public awareness for adults to place household pesticides outside the reach of children and kept away under appropriate locked storage.

Exposures at the workplace occurred principally through the inhalational and dermal routes. Dermal and inhalational routes of exposures have been identified as a common pathway of pesticide poisoning among workers. Workers are exposed through dermal absorption of direct contact of pesticides on skin during spills, or through contaminated clothing.[22] Inhalational exposures occur during fumigation or preparation of pesticides prior to usage.[23] Occupations with exposures to pesticides, such agricultural workers, pest control workers and pesticide applicators need to adopt practices which minimize exposures and offers greater respiratory and dermal protection. While an important potential mechanism, exposure from drift could not be discerned from these datasets.

Given the limited effectiveness of the regulation protecting workers, bystanders and the environment from pesticides, it is imperative that the factors leading to exposure and illness be more carefully reviewed to facilitate targeted interventions. For example, though there are regulations which protect workers, about 10,000 to 20,000 cases of pesticide poisonings among workers is diagnosed each year.[24] A comprehensive, informative, and inexpensive PRI surveillance system could include utilization, and as shown in this study, linkage of existing data sources. Better capture of data could occur through education of HCPs about PRI recognition and management, recording of salient information and recording to centralized repository, like the IPC.

A centralized repository with mandatory reporting would also be useful, since the IPC and NPDS are currently the major sources of PRI in the United States, setting up a protocol for reporting to IPC would likely be most cost effective and efficient.

LIMITATIONS

There are several limitations in this study. First, the number of cases we extracted and their characteristics could have been limited by the lack of recorded ICD-9 E-codes for some cases in the datasets; about 40% of cases in the HCF (hospital discharge and ED) data did not have E-codes recorded. E-codes were principally designed to characterize the mechanism of traumatic, injuries and would additionally provide information on ''intent.'' Notably, however, cases involving poisonings, including pesticide exposures are frequently characterized exclusively using N-codes which are more descriptive of poisonings and actually denote pesticide poisonings in five categories: hydrocyanic acid and cyanides (989.0), strychnine and salts (989.1), chlorinated hydrocarbons (989.2), organophosphate and carbamate (ICD code 989.3), and other pesticides, not elsewhere classified (ICD code 989.4), unlike other injuries, which rely on E-coding poisonings. Improvements in medical informatics software which will require completion of data fields before uploading may improve database usability.

Second, the period of our study (2010 to 2015) coincided with the change in the use of the international classification of disease from ICD-9 to ICD-10; the United States introduced ICD-10 in 2014 but coding was hybridized (ICD-9 continued to be used) through the end of 2015. The ICD-10 classification system uses new sets of injury codes for case identification, which was absent from our study, and we are unable to predict case capture going forward.

Although our study was based on the ICD-9 system, it still provides relevant information on PRI in the state and avenues for targeted intervention in addressing PRI, which is an important public health issue requiring attention. Third, difficulty in capturing every case is inherent in public health surveillance, as it depends on recognition and reporting at many different levels. In particular, none of the data systems used for this analysis likely capture most of the low dose acute and chronic exposures that may not present with symptoms/signs in the immediate future. However, case scenarios at any level can help guide intervention strategies by detecting emerging hazards regarding the agents themselves—seeing previously unrecognized adverse health effects, detecting new application technologies, or finding new uses of recognized agents. Severity or recurrent scenarios can guide interventions without counting every case.

CONCLUSIONS

Considering individual data sources, cases that were called to the IPC but did not result in triage to the ED were the highest in number, followed by IPC triaged cases, ED cases, then HD. Data linkage with de-duplication captured a higher number of cases than any database, alone. Use of existing data sources is much less expensive than active surveillance and yields a high number of cases and information that can be used for prevention. Replication of this work in other states and re-doing this study when there are many years of ICD-10 data will likely yield valuable information.

ACKNOWLEDGMENTS

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