Pesticide Poisonings in Minnesota, 2000–2015

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Abstract **This study investigated work- and nonwork-related pesticide poisonings in Minnesota. Counts, rates, trends, and spatial analysis of pesticide poisonings using data from the Minnesota Poison Control Center were produced. A total of 954 work- and 9,304 nonwork-related pesticide poisonings were reported from 2005–2015. Both showed statistically significant changes: there was a 0.52% decrease for nonwork cases and a small 0.06% decrease for work cases. After adjusting for geography and severity of medical outcomes, the prevalence of work to nonwork cases was 1.37 times higher. Work cases also had a 337% increase in major medical outcomes compared to nonwork cases. There was also a statistically significant interaction between seasonality and pesticide poisoning cases. Pesticide poisonings occurred 5.81 times more frequently during summer than during winter. This study shows the data can be mapped using caller location but should be carefully interpreted. Overall, poison control data continue to be a reliable method for pesticide poisoning surveillance.**

Introduction

Pesticides are a broad class of chemicals specifically designed to kill. A pesticide's intended target is generally an insect, plant, or small mammal but human exposure can occur. Routes of exposure include digestion, inhalation, and dermal absorption (Minnesota Department of Health, n.d.). It is estimated that the U.S. uses approximately 1 billion pounds of pesticide annually and markets over 20,000 pesticide products (Calvert et al., 2003; Calvert et al., 2004; Donaldson, Keily, & Grube, 2002). The U.S. Environmental Protection Agency (U.S. EPA) estimates approximately 20,000–40,000 work-related pesticide poisonings occur annually (Blondell, 1997).

Acute and chronic health effects have been associated with pesticide poisonings. Acute symptoms include diarrhea, pinpoint pupils, rashes, nausea, headache, and vomiting (California Department of Public Health, 2019). Chronic exposure can aggravate asthma symptoms, increase the risk of certain types of cancer and birth defects, or cause damage to immune systems (California Department of Public Health, 2019). Minnesota Poison Control Center (MN PCC) data provide information to investigate patterns of pesticide usages and exposures between different populations (Watson et al., 2005).

This study investigated suspected pesticide poisonings in Minnesota from 2000–2015 using MN PCC data. Poison control centers provide 24-hr professional assistance for all 50 states, the District of Columbia, Puerto Rico, the U.S. Virgin Islands, and the Federated States of Micronesia, American Samoa, and Guam (Wolkin, Martin, Law, Schier, & Bronstein, 2012). All poison control centers receive calls regarding potentially adverse exposures to an extensive variety of substances including medications, poisonous and nonpoisonous animals and plants, and other chemicals (Bronstein et al., 2007). The information collected during these calls is recorded using the National Poison Data System.

The majority of calls stem from the resident's home (76%), followed by healthcare facilities (16%), workplaces (1%), and schools (0.5%) (Bronstein et al., 2010). Exposures in children ages <6 years account for the majority of calls (51.9%) (Bronstein et al., 2010). Most calls are self-reported and represent either voluntarily provided information or partially incomplete information (Wolkin et al., 2012). Not every call is a poisoning incident. Calls can range from callers seeking diagnostic or treatment recommendations, reporting a suspected or known chemical poison exposure, or requesting information about a potential exposure (Wolkin et al., 2012).

Methods

Suspected pesticide poisoning cases were obtained from MN PCC data for cases with a potential relationship to work that were available from 2000–2015 and cases with no potential relationship to work available from 2005–2015. The study focused on 1) annual incidence rates, 2) trend analysis, 3) descriptive epidemiological summary analysis, and 4) spatial analysis in work- and nonwork-related pesticide poisoning cases. MN PCC

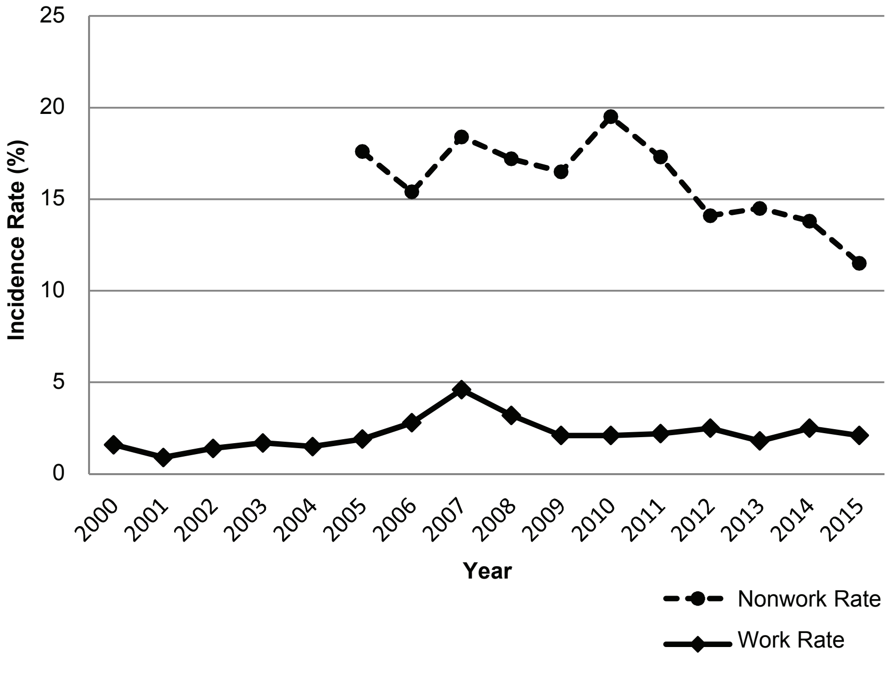
TABLE **1**

Annual Incidence Rates for Work and Nonwork Cases

Year	Work Cases	Incidence Rate	Nonwork Cases	Incidence Rate
2000	42	1.6	–	–
2001	23	0.9	–	–
2002	39	1.4	–	–
2003	45	1.7	–	–
2004	41	1.5	–	–
2005	53	1.9	902	17.6
2006	77	2.8	796	15.4
2007	125	4.6	953	18.4
2008	85	3.2	898	17.2
2009	56	2.1	869	16.5
2010	56	2.1	1,036	19.5
2011	62	2.2	925	17.3
2012	70	2.5	757	14.1
2013	50	1.8	785	14.5
2014	70	2.5	754	13.8
2015	60	2.1	629	11.5

FIGURE **1**

Pesticide Poisoning Incidence Rates



data were queried in an Access 2013 database and analysis was completed using SAS version 9.4. Cases were grouped into work and nonwork. The work case definition was based upon the Council of State and Territorial Epidemiologists (CSTE) and the National Institute for Occupational Safety and Health's (NIOSH) Occupational Health Indicators for work-related pesticide poisonings definition (CSTE, n.d.). The nonwork case definition was based on the Minnesota Environmental Public Health Tracking definition (Minnesota Department of Health, n.d.).

The cases defined were as follows.

Variables for Suspected Work Cases From 2000–2015:

- Reason for the call was occupational.
- Exposure site was at the workplace.
- Medical outcome resulted in a minor effect, moderate effect, major effect, or death; also included medical outcomes not followed, minimal clinical effects possible, and unable to follow but judged as a potentially toxic exposure.
- Excluded any suspected suicide, intentional abuse, intentional action but specific intention unknown, malicious, or unknown reasons.
- Age was ≥16 years; also included unknown adults ≥20 years, as well as adults in their 20s, 30s, 40s, 50s, 60s, 70s, 80s, and ≥90 years.
- Exposure to an agent that was a defined pesticide.

Variables for Suspected Nonwork Cases From 2005–2015:

- Reason for the call was not occupational.
- Medical outcome resulted in a minor effect, moderate effect, major effect, or death; also included medical outcomes not followed, minimal clinical effects possible, and unable to follow but judged as a potentially toxic exposure.
- Excluded any suspected suicide, intentional abuse, intentional action but specific intention unknown, malicious, or unknown reasons.
- Included all ages.
- Exposure to an agent that was a defined pesticide.

Annual Incidence Rates of Reported Work and Nonwork Cases

The annual incidence rates of reported work pesticide-poisoning cases are per 100,000 employed persons ages ≥16 years. The Geographic Profile of Employment and Unemployment provided the denominator. For nonwork cases, the U.S. Census Bureau's midyear Minnesota population estimates determined the annual number of persons residing in Minnesota.

Joinpoint Trend Analysis

Joinpoint is statistical software that uses permutation modeling for trend analysis. The "joinpoints" estimate where changes in trends can occur (Kim, Fay, Feuer, & Midthune, 2000). The program tests if the joinpoints, or changes in trend, are statistically significant (Kim et al., 2000). Trend analyses of the annual incidence rates were produced for work and nonwork cases to understand and compare the overall trends of these groups.

Epidemiological Summary Analysis

Summary analyses were performed for age, sex, severity of medical outcomes, and geographical factors (metro area and nonmetro area) in work and nonwork cases. We used as a reference a map created by the Minnesota Department of Agriculture (2016) that breaks the state into 10 different areas, with the metro area being Area 10 and the nonmetro areas being Areas 1–9. The metro area counties included Anoka, Carver, Dakota, Hennepin, Scott, Ramsey, and Washington.

Additional frequency tables were generated to describe pesticide usage and differences between work and nonwork cases. Large pesticide categories included disinfectants, fungicides (nonmedicinal), fumigants, herbicides, insecticides, repellents, and rodenticides. Caller location provided the ZIP code of where the individual called MN PCC to report the pesticide poisoning incident. This caller location was analyzed among the nonwork cases to identify the most frequent location, as well as to determine spatial analysis. This study also looked at work- and nonwork-related cases by geography. Related cases were defined as pesticide poisoning cases in people who were exposed from the same pesticide poisoning exposure (incident).

Poisson regression models were performed in SAS version 9.4 to produce unadjusted and adjusted risk ratios with 95% confidence intervals (*CI*s) in work versus nonwork cases. Regression models were adjusted for sever-

TABLE **2**

Distribution of Pesticide Poisoning Cases

	Work Cases (*n* = 954) # (%)	Nonwork Cases (*n* = 9,304) # (%)
Age		
<16 years (%)	0	64.5
≥16 years (%)	100	35.1
Average age (years)	36	20
Median age (years)	33	7
Mode age (years)	20	2
Sex		
Male	549 (57.5)	4,717 (50.7)
Female	320 (33.5)	4,524 (48.6)
Severity (%)		
Minor effects	87.3	98.0
Major effects	12.5	2.2
Geography (%)		
Nonmetro areas	82.8	75.9
Metro areas	17.2	24.1
Pesticides: Category description		
Disinfectants	428 (44.9)	4 (<0.1)
Insecticides	207 (21.7)	4,979 (53.5)
Herbicides	191 (20.0)	1,114 (12.0)
Fungicides (nonmedicinal)	99 (10.4)	125 (1.3)
Repellents	12 (1.3)	1,901 (20.4)
Rodenticides	9 (0.9)	1,168 (12.6)
Fumigants	8 (0.8)	12 (0.1)
Fertilizers	0	1 (<0.1)
Pesticides: Generic description		
Anticoagulant: Long-acting, superwarfarin rodenticide	0	**907**
Borate/boric acid	0	**1,859**
Chlorophenoxy	**38**	443
Glyphosate	**58**	342
Hypochlorite	**106**	0
Insect repellent	0	**1,475**
Naphthalene	3	103
Organophosphate	**41**	269
Pyrethrin	4	**538**
Pyrethroid	**104**	**1,899**

Note. All cases with an unknown age (40 cases) or sex (148 cases) were not considered. Bolded values represent the top 5 generic pesticide descriptions for work and nonwork cases (not including other/unknown description).

FIGURE **2**

Distribution of Pesticide Poisoning Cases by Season

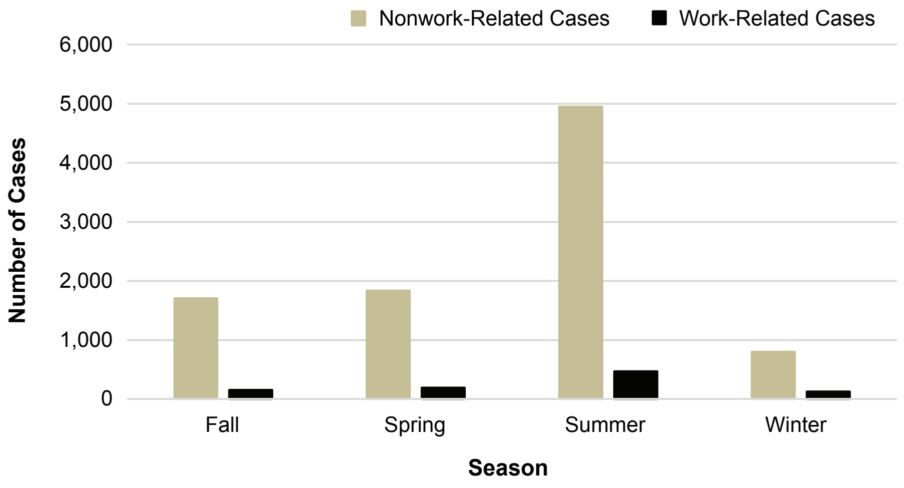


TABLE **3**

Seasonal Pairwise Comparisons With Chi-Square and *p*-Values

Pairwise Comparison	Chi-Square Value	Unadjusted *p*-Value	Adjusted *p*-Value (Bonferroni)
Winter versus spring	12.1	**.0005**	**.0030**
Winter versus summer	24.6	**<.0001**	**<.0001**
Winter versus fall	18.7	**<.0001**	**<.0001**
Summer versus spring	1.3	.2518	1.0000
Summer versus fall	0	.8607	1.0000
Spring versus fall	1.1	.2859	1.0000

Note. Bolded *p*-values are statistically significant.

ity and geography. Severity was grouped into minor and major medical outcomes. Additionally, a Poisson regression model was performed to look at sex differences in work cases only.

We created a new variable, season, that grouped MN PCC pesticide poisoning cases into four seasons: spring (March 1–May 31), summer (June 1–August 31), fall (September 1–November 30), and winter (December 1–February 28 [29 in a leap year]). Pairwise comparisons among all seasons by work exposure were tested with their associated chi-square and *p*-values. We then performed a Bonferroni adjustment to obtain adjusted *p*-values. A Poisson log linear model was fitted to test winter against all other seasons by work exposure.

Spatial Analysis

Maps were generated in ArcMap 10.3 to spatially display the distribution of work and nonwork cases. This study used the Minnesota Department of Transportation to download the Minnesota county boundaries shapefile. The total work and nonwork rates by total area population were calculated (10 total areas) per 10,000 persons. The Minnesota Department of Agriculture (2019) clusters counties of similar geology, soils, and crops together.

Results

Annual incidence rates were identified for work and nonwork pesticide poisoning cases (Table 1). Trend analyses were created for work and nonwork pesticide poisoning cases. There was a very small but statistically significant 0.08% average annual increase for work cases (standard error = 0.03, *p*-value < .04) (Figure 1). This extremely small increase suggests that the annual incidence rate trend for work cases was stable throughout 2000–2015. There were two “joins” or directional trend changes detected within nonwork cases (Figure 1). From 2005–2010, there was a small but not statistically significant 0.29% average annual increase. Then from 2010–2015, there was a statistically significant 25% annual decrease (standard error = 0.3, *p*-value < .01).

A comparative trend analysis between work and nonwork annual incidence rates was completed for 2005–2015. Both work and nonwork annual incidence rates decreased during this period. There was a very small but statistically significant 0.06% decrease for work cases and a small but statistically significant 0.52% decrease for nonwork cases (work *p*-value < .05, nonwork *p*-value < .01).

The distribution of work cases (2000–2015) and nonwork cases (2005–2015) by age, sex, severity, and geography are presented in Table 2. The median and mode ages were compared because age distributions were heavily skewed. Most work cases were much older than nonwork cases: 20 years versus 2 years, respectively. The median age for work cases was 33 years, while the median age for nonwork cases was 7 years. There was a higher percentage of males (58%) to females (34%) among work cases, while the percentage of males (51%) and females (49%) in nonwork cases was relatively similar. Cases were categorized into metro areas (urban) and nonmetro areas (rural). Both work and nonwork cases occurred with greater frequency in nonmetro areas, as well as with greater frequency in severity resulting in minor medical outcomes.

The majority of nonwork cases were exposed at the resident’s home (91.2%), while every other exposure site—other residence, public area, workplace (exposure reason was not occupational related), school, restaurant/food service, healthcare facility, unknown, and other—made up <6% of the nonwork cases.

Large pesticide categories were identified for all work and nonwork cases (Table 2). The top 4 pesticide categories included disinfectants (45%), insecticides (22%), herbicides (20%), and fungicides (10%). The top 4 pesticide categories for nonwork cases included insecticides (54%), repellents (20%), rodenticides (13%), and herbicides (12%).

The top 5 generic pesticide descriptions were also identified for all work and nonwork cases (Table 2). The top 5 generic pesticide descriptions for work cases included hypochlorite (disinfectant), pyrethroid (insecticide), glyphosate (herbicide), organophosphate (insecticide), and chlorophenoxy (herbicide). The top 5 generic pesticide descriptions for nonwork cases included pyrethroid (insecticide), borate/boric acid (insecticide), insect repellent (repellent), pyrethrin (insecticide), and anticoagulant such as the long-acting superwarfarin (rodenticide).

Related cases for work versus nonwork cases by geography were identified. Both work cases (87%) and nonwork cases (92%) occurred with greater frequency with single pesticide poisoning events (no related cases). Work cases with at least one related case, however, showed an overall higher percentage (14%) compared with nonwork cases with at least one related case (8%), which might suggest work cases have a higher risk of involving multiple individuals than a single pesticide exposure (event).

There was a 37% increase in the prevalence of work cases versus nonwork cases in nonmetro areas. In addition, there was a 337% increase in the prevalence of work cases resulting in major medical outcomes compared with nonwork cases. The prevalence of male work cases was 1.72 times higher than the prevalence of female work cases (95% *CI* [1.49, 1.97]).

A chi-square test of independence was performed to examine the relationship between seasonality and all work exposure cases (Figure 2). There was a significant relationship between these two variables, $\chi^2(3, N = 10{,}258) = 26.43$, $p < .0001$. After Bonferroni adjustment of all pairwise comparison *p*-values, only winter remained statistically different from all other seasons. Statistically significant interactions between seasons and work exposure cases were generated (Table 3). Pesticide poisoning cases occurring in the summer were 5.81 times higher compared with pesticide-poisoning cases occurring in the winter (Table 4).

TABLE **4**

Parameter Estimates and 95% Confidence Intervals for Work Exposure by Seasons

Parameter	Estimate	Standard Error	Wald 95% Confidence Interval	Wald Chi-Square Value	*p*-Value
Intercept	4.5	0.0450	4.38, 4.55	9,849.30	<.0001
Fall	0.7	0.0401	0.62, 0.77	300.91	<.0001
Spring	0.8	0.0395	0.70, 0.86	388.49	<.0001
Summer	1.8	0.0354	1.69, 1.83	2,464.66	<.0001
Winter	0	0	0, 0		
Scale	1.0	0	1.00, 1.00		

Maps for work and nonwork rates by total area population per 10,000 persons were generated (Minnesota Department of Agriculture, 2019). The spatial distribution for work and nonwork rates were similar (Figures 3 and 4). The Northwest Red River area was heavily concentrated for work cases, however, while the Central Sands area was heavily concentrated for nonwork cases.

Discussion

There were 9,304 nonwork pesticide poisoning cases reported from 2005–2015 and 968 work pesticide poisoning cases reported from 2000–2015. It was determined that 14 out of 968 work cases occurred in individuals <16 years and thus these cases were excluded from summary analyses. Trend analysis of the annual incident rates for work versus nonwork cases between 2005–2015 produced a statistically significant 0.52% decrease for nonwork cases and a very small but statistically significant 0.06% decrease for work cases. Annual incident rates for work cases from 2000–2015 demonstrated a statistically significant 0.08% average annual increase. The small average annual increase suggests a fairly flat trend for pesticide poisonings with a relationship to work. Annual incidence rates for nonwork cases suggest a statistically insignificant 0.29% average annual increase through the years 2005–2010. We see, however, that there was a statistically significant 25% annual decrease through the years 2010–2015. The cause of this decline is unknown.

Descriptive analyses investigated age, sex, severity of medical outcomes, and geographical factors in all work and nonwork pesticide poisoning cases. As the age distribution is log-linear, we provide the mode and median. For work cases, the mode and median age suggest prevention measures should target adults in their 20s and 30s. The male-to-female case ratio suggests greater exposure risk for males in the work setting. The results also show that more work cases happen in nonmetro areas than in metro areas. Potential areas to promote awareness and prevention could focus on the median age, males, predominantly rural locations, and factor in the pesticide categories of exposure and work in agriculture or agricultural settings.

For nonwork cases, the median age was 7 years, which suggests prevention measures should target children <7 years. Resident homes comprised 91% of the caller locations for nonwork cases, suggesting education might be warranted on appropriate insect repellent application as well as proper storage of products in homes with infants and young children present. There were also more nonwork cases in nonmetro areas than in metro areas. As repellents are predominantly used for outdoor reasons, it correlates with most pesticide poisoning cases occurring in rural areas of Minnesota.

The results also showed that significantly more work cases result in major medical outcomes compared with nonwork cases. Most work cases involve disinfectants, insecticides, FIGURE **3**

Rates of Work-Related Pesticide Poisoning Cases by Area

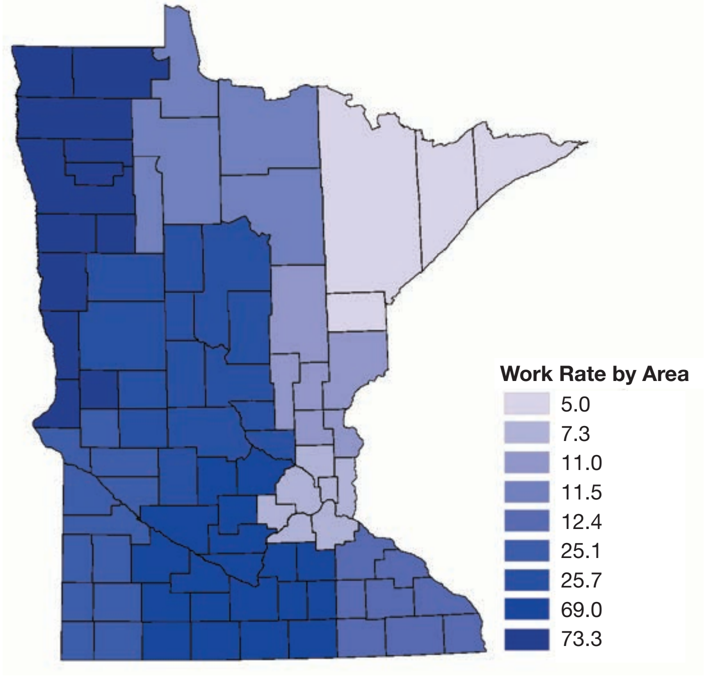
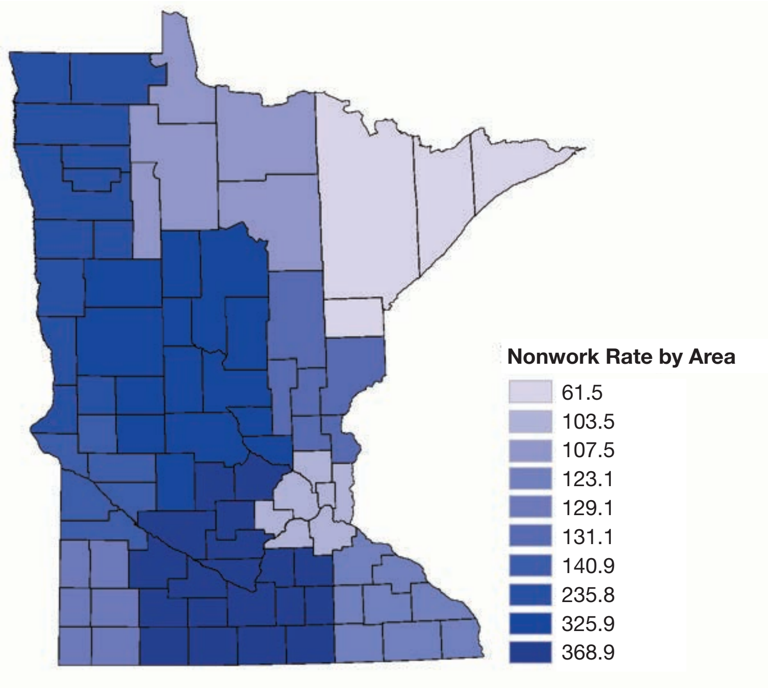


FIGURE **4**

Rates of Nonwork-Related Pesticide Poisoning Cases by Area



and herbicides, while most nonwork cases involve insecticides, repellents, and rodenticides. This finding suggests intervention efforts should target work and nonwork cases differently. Education about correct application and storage of pesticides should be in correlation with the seasonality of product usage. Proper use of insecticides and repellents in nonwork cases might decrease the number of nonwork cases. Protective equipment during the application of disinfectants, insecticides, and herbicides might decrease the number of work cases.

Both work and nonwork cases had a greater frequency of no related cases compared with having at least one related case. The proportion of having at least one related case was higher in work cases (14%) than in nonwork cases (8%), as well as higher in nonmetro areas for work cases (12%) than in nonwork cases (6%). The related cases for work cases might be due to inexperience, lack of awareness of bystanders, or a change in protocol or work environment. The related cases for nonwork cases might involve young children improperly applying insect repellents for each other—and thus exposing themselves and others to pesticides.

Season has a strong association with pesticide poisoning incidents. Pesticide poisoning cases occurring in the summer were 5.81 times higher compared to pesticide poisoning cases occurring in the winter. These odds might potentially change as climate change progresses. Longer warm periods could lead to an increased use of pesticides in response to an increase in mosquito and other insect populations.

Lastly, incidence rates by total area population were calculated and displayed in ArcMap to allow for comparison across all county areas (Figures 3 and 4). The distribution of work versus nonwork cases was similar. Work cases were predominantly in the Northwest Red River, West Central, Southwest Central, and South Central areas, while the nonwork cases included those areas as well as the Central Sands area. Some potential explanations for differences in nonmetro counties could include low prevalence of agriculture, access to healthcare facilities, land use, and pesticide usage.

Poison control center data are the best surveillance information available to estimate the number of pesticide poisonings for both work and nonwork cases annually. The reliability of poison control center data for research and surveillance depends on its completeness and accuracy. The American Association of Poison Control Centers (AAPCC) created a manual for all poison control centers to collect consistent data. Errors that are commonly made include the use and interpretation of abbreviations (Thienes, 1995, 2002), the initial substance reported (Lubbert, McVoy, Seifert, & Jacobitz, 2005), and the failure to properly document information (Seifert et al., 2005). Most U.S. poison control centers automatically upload a portion of the data to the AAPCC to conduct surveillance at the national level. Manual review of all poison control center records is impractical due to the large volume of calls (Jaramillo, Marchbanks, Willis, & Forrester, 2010). Because poison control centers serve almost the entire U.S. population, the data are useful for monitoring pesticide poisonings nationally, even though poison control centers capture only approximately 10% of acute occupational pesticide-related illness cases (Calvert et al., 2003).

Some limitations of poison control center data include, but are not limited to (Minnesota Department of Health, n.d.):

- Poison control center calls stem from a variety of reasons, including medical counseling for poisoning.
- Data are acquired through telephone calls, which limits data collection to those who have access to telephones, as well as to those who have knowledge of poison control center services.
- Mapping the data is highly dependent on whether the location of the caller was the same as the site of exposure. This study tried to determine whether the caller and site of exposure were the same. For work cases, call location occurred at a healthcare facility in about 46% of cases (438 out 954 cases) and about 1% was unknown. Assuming that individuals traveled to the nearest available healthcare facility and that the majority of healthcare facilities that called the poison control center were rural, one might assume that the call location was within the same county or an adjoining county.
- Some work cases might be reported as nonwork cases if people are reluctant to report a work site injury or exposure.
- Duplicate case numbers were removed to decrease the probability that more than one call was made for the same event. It is possible, however, that numerous calls for the same poisoning event might have been reported as different case numbers.

Conclusion

As stated above, poison control center data have limitations but continue to serve as an important resource in pesticide poisoning surveillance in the U.S. This study used MN PCC data to conduct an assessment and overview of both Minnesota work- and nonwork-related pesticide poisoning exposures. Further studies can use these results to conduct more focused studies about geography, gender/sex, seasonality, severity, and pesticide usage. As discussed earlier, the annual incidence rates for nonwork cases seem to be decreasing over time, which suggests efforts to promote education and awareness in nonwork-related groups are effective. The annual incidence rates for work cases seem to be stable; however, these rates might be affected in the next decade with changes in climate and agricultural practices.

Acknowledgement: This research was funded by a grant from NIOSH (5U60OH009855-08) supporting the Minnesota Occupational Safety and Health Surveillance Program. Additional support from a Centers for Disease Control and Prevention cooperative agreement (5NU38EH000617-08) funded the Minnesota Environmental Public Health Tracking Network Implementations Program.

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