J. Med. Toxicol. (2011) 7:164–171
DOI 10.1007/s13181-011-0152-8

CDC/ATSDR TOXICOLOGY REPORT

Surveillance Data on Pesticide and Agricultural Chemical Releases and Associated Public Health Consequences in Selected US States, 2003–2007

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Published online: 5 May 2011

Abstract
Background While pesticides and agricultural chemicals are used to increase crop production and to reduce the spread of disease, their toxic nature also has the potential to threaten human health. Releases of pesticides and agricultural chemicals have resulted in human illness and death. This analysis examines releases of pesticides and agricultural chemicals and their associated injuries captured by the Hazardous Substances Emergency Events Surveillance (HSEES) system from 2003–2007.
Methods Simple descriptive statistics are presented. Comparisons were made to data from all HSEES events when possible.
Results Analysis of the data shows that farm workers are at particular risk for injury and that the most frequent months for releases of pesticides and agricultural chemicals were the spring planting months of April through June. Releases of pesticides and agricultural chemicals occurred more often during transport, had higher frequencies of patient decontamination associated with them, and lower frequencies of evacuation and shelter-in place orders compared with all HSEES events.
Conclusion Since exposures are precipitated by behavioral and environmental factors, especially in occupational settings, future interventions targeting employers, and transporters of agricultural chemicals, as well as physicians, are recommended. These interventions should be customized to fit local conditions.

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Keyword Pesticides

Introduction

Many varieties and large quantities of pesticides and agricultural chemicals are being manufactured, transported, and applied worldwide. The United States (USA) uses approximately two billion pounds of licensed pesticides every year, which is roughly one fifth of the total global pesticide use [1]. Pesticides and agricultural chemicals can improve crop production and pest management, but they can simultaneously harm non-target organisms, such as humans.

The symptoms from acute pesticide exposure poisoning can be respiratory, gastrointestinal, allergic, and neurologic in nature [1]. The Environmental Protection Agency (EPA) estimates that 10,000–20,000 physician-diagnosed pesticide poisonings occur each year among the approximately 3,380,000 US agricultural workers [2]. The full extent of human poisonings from pesticides and agricultural chemicals, however, is difficult to define in the USA because there is no comprehensive national system designed specifically for tracking health effects associated with agricultural chemical exposures [3–5]. An analysis of occupational pesticide illness data in California found that the number of reported cases was likely an undercount due to factors such as physician misdiagnosis and workers not seeking or not having access to health care [6].

The Hazardous Substances Emergency Events Surveillance (HSEES) system was initiated by the Agency for Toxic Substances and Disease Registry (ATSDR) in 1990 to collect data on the acute and the threatened releases of hazardous substances (including pesticides and agricultural chemicals) and the associated public health impacts. Data were collected through 2009 when the HSEES program was terminated and replaced with the National Toxic Substance Incidents Program which expands on HSEES' mission. Although it was only available in the selected states, HSEES was considered the most complete picture of non-petroleum hazardous substance incidents and associated acute public health effects in the United States [7]. The Petroleum Exclusion clause of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 prohibited ATSDR from becoming involved with incidents where any form of petroleum was released that had not been refined to the point of becoming a specific chemical product, such as pure xylene. HSEES did, however, record information about petroleum if it was released with another qualifying substance.

While HSEES was operational, an event was defined as an uncontrolled and/or illegal acute release of any hazardous substance meeting specific pre-established quantity and other criteria [8]. The threatened releases of the qualifying amounts of hazardous substances were included if the threat led to an evacuation or other action to protect the public health. State health department personnel collected information about acute hazardous chemical events from a variety of sources (e.g., records and oral reports of state environmental agencies, police and fire departments, and hospitals). Data were entered into a secure web-based application that enabled ATSDR to instantly access all data except for identifiable information.

Information collected for HSEES events included the location, industry involved, area impacted, proximity to vulnerable populations, chemicals released, number of victims, evacuations, and contributing factors for the event. The HSEES system collected data on the primary (root) contributing factor and the secondary (immediate) contributing factors related to an event. Information on contributing factors was either reported by the notification source or determined using reports from poison control centers, state environmental agencies, and other sources.

For events occurring during 2003–2004, industry codes for the type of industry responsible for each HSEES event were assigned according to the 1990 Industrial Classification System of the U.S. Census Bureau [9]. The 2002 North American Industry Classification System was used to categorize the industries for events occurring during 2005–2007 [10]. The area impacted by an event was defined as the location where the substance was dispersed. Geographic Information Systems or health department records were used to determine possible locations of vulnerable populations (i.e., child day care centers, hospitals, nursing homes, and schools) within close proximity to the event, defined as within a 1/4 mile radius. In HSEES, a victim was defined as a person experiencing at least one documented adverse health effect (e.g., respiratory irritation or chemical burns) that likely resulted from the event and occurred within 24 h after the release. The HSEES system did not identify the immediate cause of the adverse health effect, other than that it occurred during the course of the event.

HSEES chemical classification included 16 categories: acids, ammonia, bases, chlorine, formulations, hetero-organics, hydrocarbons, mixtures across categories, oxy-organics, paints and dyes, agricultural chemicals and pesticides, polychlorinated biphenyls, polymers, volatile organic compounds, other inorganic substances, and other substances. The mixtures across the categories consisted of substances with components from more than one of the other 15 chemical categories. The category "other inorganic substances" comprised of all inorganic substances other than acids, bases, ammonia, and chlorine and included chemicals such as nitrogen oxide and hydrogen sulfide. The "other" category consisted of chemicals, such as asbestos, that could not be classified into any of the other 15 chemical categories.

The primary objective of this study is to describe HSEES events involving pesticides or agricultural chemicals from 2003 to 2007 as well as describe the prevention efforts in one state to minimize or eliminate these releases and reduce the adverse public health consequences associated with such releases.

Methods

The analysis was restricted to HSEES events in which a pesticide or agricultural chemical was released. Events where more than one pesticide or agricultural chemical was released and events where pesticides or agricultural chemicals were released along with other chemicals were also excluded. This was done for ease of interpretation so any result seen could be attributed to the specific pesticide or agricultural chemical released versus the other chemicals released. The analysis included the events of single chemical releases captured by HSEES for 2003–2007 where the chemical category was "pesticides/agricultural" or the question "Was this substance used as a pesticide?" was marked "yes." To narrow the focus to the analysis of agricultural chemicals, chemicals which were used primarily for sanitation in medical and laboratory settings were removed from the analysis. These chemicals were ethylene oxide; chlorine; chlorine bleach, not otherwise specified; and sodium hypochlorite.

Eleven states participated in HSEES during the entire period covered by this report: Colorado, Iowa, Louisiana, Minnesota, New York, North Carolina, Oregon, Texas, Utah, Washington, and Wisconsin. Six additional states participated during the portions of the period: Alabama (2003), Florida (2005–2007), Michigan (2005–2007), Missouri (2003–2005), Mississippi (2003), and New Jersey (2003–2005 and 2007). Descriptive statistics are presented for the resultant construct "pesticide- and agricultural chemical-related events" including the contributing factors, involved industries, time of release, substances, victims, evacuations, in-place sheltering, decontamination, and public health response. Comparisons are made to all events in HSEES for reference only.

Results

Of the 40,667 HSEES events from 2003 to 2007, 1,753 (4.3%) involved the release of a single pesticide or agricultural chemical. Of these 1,753 pesticide- and agricultural chemical-related events, 53.9% were transportation related and 46.1% occurred in fixed facilities compared with 28.1% of all HSEES events involving transportation and 71.9% of all events occurring in fixed facilities. Human error (n=1,007, 57.4%) and equipment failure (n=597, 34.1%) were the most frequent primary causal factors contributing to pesticide- and agricultural chemical-related events. Of the 1,077 events where a secondary causal factor was reported, the factors most frequently reported were improper filling, loading, or packing (n=318, 31.6%); derailment/rollover/capsizing (n=277, 27.5%); and overspray/misapplication (n=118, 11.7%). For the 255 events where extreme weather conditions were present, rain was the most frequently reported type of weather condition (n=105, 41.2%).

The two industries most frequently reported as involved in pesticide- and agricultural chemical-related events were transportation/warehousing (n=422, 24.1%) and agriculture, forestry, fishing, and hunting (n=417, 23.8%). Wholesale trade (n=201, 11.5%) and manufacturing (n=154, 8.8%) also accounted for a large percentage of the events (Table 1). The other services and agriculture industries categories also accounted for a significant percentage of events with victims (21.2% and 20.7%, respectively).

The percentage of pesticide- and agricultural chemical-related events by month ranged from 3.6% in February to 17.9% in May, with the spring planting months of April, May, and June as having the highest percentage of events (14.1%, 17.9%, and 15.0%, respectively). For all HSEES events, the percentage of events by month had a narrower range with the lowest percentage occurring in February (6.9%) and the highest percentage occurring in June (9.9%). The peak months for all HSEES events were June, July, and August (9.9%, 9.6%, and 9.5%, respectively).

Besides mixtures, a total of 344 standard substance names comprised the pesticide- and agricultural chemical-related events. Pesticide not otherwise specified (7.8%) and the nitrogen fertilizer (5.9%) were the substances most frequently released (Table 2).

Victims

There were 487 victims in 217 pesticide- and agricultural chemical-related events. A higher percentage of these events (12.3%) involved victims when compared with all HSEES events (8.7%) during 2003–2007. The month with the most pesticide- and agricultural chemical-related victims was May (n=112, 23.0%). There were more male victims of the pesticide- and agricultural chemical-related events than females (61.3% and 38.7%, respectively).

Members of the general public (n=230, 47.2%) and employees (n=207, 42.5%) constituted the majority of victims, followed by responders (n=38, 7.8%), and students (n=12, 2.5%). Of the 38 responder victims, 20 (52.6%) were career firefighters, eight (21.1%) were police officers, six (15.8%) were firefighters, type not specified, and four (10.5%) were emergency medical technicians (EMTs). Only ten (26.3%) of the 38 responders were trained HazMat responders.

Table 1 Industries involved in releases of pesticides and agricultural chemicals, Hazardous Substances Emergency Events Surveillance, 2003–2007

Industry category	Frequency	Percentage
Transportation and warehousing	422	24.1
Agriculture, forestry, fishing, and hunting	417	23.8
Wholesale trade	201	11.5
Manufacturing	154	8.8
Unknown	143	8.2
Other services	120	6.8
Other	76	4.3
Retail trade	70	4.0
Administrative and support and waste management and remediation services	51	2.9
Not an industry	38	2.2
Public Administration	37	2.1
Utilities	24	1.4
Total[a]	1,753	100.1

[a] Percentages do not total 100% because these were rounded off

Table 2 Substances released in 15 or more releases of pesticide and agricultural chemicals, Hazardous Substances Emergency Events Surveillance, 2003–2007

Substance	Frequency	Percentage
Pesticide NOS[a]	136	7.8
Nitrogen fertilizer	104	5.9
Fertilizer NOS[a]	87	5.0
Urea ammonium nitrate	87	5.0
Methylene chloride	58	3.3
Fertilizer, nitrogen–phosphorus–potassium	41	2.3
Glyphosate isopropylammonium salt	39	2.2
Malathion	37	2.1
Herbicide NOS[a]	36	2.1
Chlorpyrifos	35	2.0
Urea	34	1.9
Magnesium chloride	31	1.8
Acrolein	27	1.5
Pendimethalin	23	1.3
2,4-D	19	1.1
Copper sulfate	15	0.9

[a] Not otherwise specified

Of the 245 employee and responder victims, 201 (82.0%) reported wearing no personal protective equipment. Personal protective equipment use was unknown for eight (3.3%) victims. Twenty-five firefighter victims (10.2%) wore fire fighter turn-out gear (five with respiratory protection) and 11 employee victims (4.5%) reported using other types of protection, such as gloves, eye protection, hard hats, or steel-toed shoes.

The 487 victims sustained 788 injuries. The most frequently reported injuries were respiratory system problems (n=228, 28.9%), followed by gastrointestinal problems (n=119, 15.1%; Table 3). Most of the pesticide- and agricultural chemical-related victims were treated at a hospital (n=204, 41.9%) or experienced injuries within 24 h of the event that were reported by officials (e.g., fire department, EMT, police, poison control center; n=117, 24.0%). The frequency of the latter was higher compared to all HSEES events (24.0% vs. 6.8%). The remaining victims were treated on-scene (n=58, 11.9%), admitted to a hospital (n=36, 7.4%), seen by a physician within 24 h (n=27, 5.5%), observed at a hospital but received no treatment (n=22, 4.5%), died (n=13, 2.7%), or the disposition was unknown (n=10, 2.1%). The agriculture industry had the highest percentage of victims overall (33.5%) as well as the highest percentage of employee victims (39.1%) and victims from the general public (30.6%).

Age was available for 418 of the victims. One hundred ninety-five (46.7%) victims were between 20 and 44 years of age; 87 (20.8%) were between 45 and 64 years of age; 84 (20.1%) were between 5 and 14 years of age; 19 (4.5%) were 65 years of age or greater; 18 (4.3%) were between 15 and 19 years of age; and 15 (3.6%) were 4 years of age and under. There were more victims aged 14 and under in pesticide- and agricultural chemical-related events (23.7%)

Table 3 Symptoms and injuries involved in releases of pesticide and agricultural chemicals, Hazardous Substances Emergency Events Surveillance, 2003–2007

Injury	Frequency	Percentage
Respiratory system problems	228	28.9
Gastrointestinal problems	119	15.1
Dizziness/central nervous system symptoms	83	10.5
Headache	83	10.5
Eye irritation	72	9.1
Trauma[a]	61	7.7
Skin irritation	56	7.1
Shortness of breath (unknown cause)	49	6.2
Other	19	2.4
Burns[b]	13	1.6
Heart problems	5	0.6
Total[c]	788	99.7

[a] Five were chemical-related and 56 were not chemical-related

[b] Three were thermal burns, seven were chemical burns, two were both chemical and thermal burns, and burn type was missing for one victim

[c] Percentages do not total 100% because these were rounded off

compared with all HSEES events (13.6%). This excess was due to a single event in which 57 children at a school were injured when there was an overspray from a nearby field.

Evacuations, Shelter In-Place Orders, and Decontaminations

Evacuations were ordered in 3.5% of pesticide- and agricultural chemical-related events compared with 6.3% in all HSEES events. Although pesticide- and agricultural chemical-related events had a lower proportion of evacuations, they had slightly longer evacuation lengths (average of 5.4 h) compared with all HSEES events (average of 4.3 h). Shelter in-place orders occurred in 0.5% of pesticide- and agricultural chemical-related events compared with 1% of all HSEES events. Decontamination status was reported for 90% of the 487 victims in pesticide- and agricultural chemical-related events. The majority (71.5%) of the victims were not decontaminated. Of those victims who were decontaminated, decontamination at the scene occurred almost four times as often as decontamination at the medical facility (63 events vs. 16). Compared with all HSEES events, the percentage of victims decontaminated at both the medical facility and the scene was four times higher for pesticide- and agricultural chemical-related events (10.5% and 2.6%, respectively). The percent of events with uninjured persons decontaminated, however, was only slightly higher for pesticide- and agricultural chemical-related events than for all events (2.3% and 1.9%, respectively).

Response

Of the 1,741 events with information on who responded to the event, no one responded in 201 (11.5%) events. In 556 (31.9%) events, there were multiple types of responders: 298 events reported two categories of responders; 140 events reported three categories; 74 events reported four categories; and 34 events reported five or more categories. A total of 13 responder categories were reported (Table 4); the company's response team (*n*=994, 39.3%) was most likely to respond to pesticide- and agricultural chemical-related events, followed by the fire department (*n*=381, 15.1%) and law enforcement agency (*n*=340, 13.4%).

Discussion

Differences between pesticide and agricultural events and all HSEES events were in the reporting of victims, evacuation, month of release, transportation, and industry data. The higher percentage of injuries reported by officials (e.g., fire department, EMT, police, poison control center) could be because victims may not seek care at a hospital or doctor's office for fear of repercussion from employers, lack of insurance, or language barriers [5, 6]. Poison control centers, however, offer a free confidential response, and the general public uses them frequently. This may explain the large amount of injuries reported through poison control centers.

The lower percentages of evacuations and shelter in-place orders among pesticide- and agricultural chemical-related events, when compared to all HSEES events could be due to the adherence of official evacuation guidelines specific to pesticides and agricultural chemicals. An example might be insufficient circumstance criteria to warrant evacuations or shelter in-place. It may also be due to the remoteness of the location of releases of pesticides and agricultural chemicals and hence a lower perceived threat and need to evacuate or shelter in-place. Further

Table 4 Responders involved in releases of pesticides and agricultural chemicals, Hazardous Substances Emergency Events Surveillance, 2003–2007

Responder	Frequency	Percentage
Company's response team	994	39.3
Fire department	381	15.1
Law enforcement agency	340	13.4
Certified HazMat team	188	7.4
Environmental agency/EPA response team	179	7.1
Third Party Cleanup Contractors	113	4.5
Emergency Medical Services	103	4.1
Other	78	3.1
State, County, or Local Emergency managers/coordinators/planning committees	48	1.9
Department of works/utilities/transportation (includes Coast guard)	45	1.8
Health department/health agency	41	1.6
Hospital/Poison Control Center	17	0.7
Specialized multiagency teams	3	0.1
Total[a]	2,530	100.1

EPA Environmental Protection Agency

[a] Percentages do not total 100% because these were rounded off

investigation is needed for factors contributing to fewer evacuations in pesticide- and agricultural chemical-related events compared with other hazardous substances events.

This analysis showed that the most frequent months for releases of pesticides and agricultural chemicals were the spring planting months of April, May, and June, which is consistent with a previous analysis [11]. This is most likely due to increased agricultural activities such as field preparation and planting during the spring and early summer months. HSEES events as a whole are distributed more uniformly throughout the year (high of 9.9% in June and low of 6.9% in February), while the releases of pesticides and agricultural chemicals are higher during spring months and drop off more dramatically during the winter months (high of 17.9% in May and low of 3.6% in February). The timing of pesticide- and agricultural chemical-related events is important for targeting prevention outreach. It may be best to conduct outreach to farm workers right before planting season so recall is optimized.

A potential reason for the higher number of pesticide- and agricultural chemical-related events during transportation (when compared with all HSEES events) may be improperly secured loads. Almost a third of the pesticide- and agricultural chemical-related events involved improper filling, loading, or packing. Another reason may be the poor skills of the drivers since almost one fifth of the events were due to derailment/rollover/capsizing. Other factors such as container size and load ability, mode of use (vehicle assisted application), and site-to-use distances should be explored further. The outreach efforts targeting transporters of agricultural chemicals should be undertaken, such as training on properly securing loads and driver safety courses.

The agriculture industry was frequently involved in pesticide- and agricultural chemical-related events and had the highest percentage of employee victims. The Department of Labor estimates the number of hired farm workers at 2.5 million [12]. Dermal, oral, and inhalation are the main routes of exposure for pesticides and agricultural chemicals with oral considered the most lethal and inhalation, the most common. Both behavioral and environmental factors contribute to pesticide- and agricultural chemical-related exposures. Ingestion in farm workers, due to the improper washing of food and/or hands, is a common problem [1–3, 13]. Farm workers often spend long days in fields where environmental factors, such as the lack of proper hand washing stations supplied with soap, water, and towels, prevent them from decontaminating themselves prior to eating [3, 5]. Policies for hand washing stations in fields should be further developed, promoted, and enforced.

Other known behavioral factors linked with exposure to pesticides and agricultural chemicals include the storage of these chemicals in containers other than the original labeled container and cross contamination due to not laundering field clothes separately [13–15]. This analysis found that over half of the pesticide- and agricultural chemical-related events were due to human error and could have resulted from these behavioral factors.

With 24% (n=117) of the victims of pesticide- and agricultural chemical-related events being 19 or younger, HSEES data findings corroborate that children, in general, are a population of concern for acute pesticide and agricultural chemical exposure. Almost half of the children victims in this analysis were exposed at a single event involving a pesticide drifting from the site of application to where the children were present. The EPA lists field application drift as an important environmental factor leading to exposure to pesticides [2].

The releases of pesticides and agricultural chemicals occurred in many settings other than agriculture and manufacturing. Slightly over half of the events occurred in industries that do not manufacture, sell, or transport pesticides or agricultural chemicals. One way to decrease the number of releases of pesticides and associated injuries in these other settings is through Integrated Pest Management. Integrated Pest Management is an approach that combines commonsense practices with information on the life cycle of pests to focus on ways to control pests while reducing the use of pesticides [16]. It can be thought of as a compendium with a series of pest management evaluations, decisions, and controls aimed at reducing pesticide use [16]. Methods for reducing pests that do not involve the use of chemicals are promoted to be tried first [5]. Traps, crop rotation, and natural predators are some methods that should be considered when weighing the risks and benefits of using chemicals.

Very little research has been conducted concerning best practices for appropriately targeted prevention of exposure to pesticides and agricultural chemicals [3]. Farm workers come from a variety of culturally diverse populations [17]. As a result, attempts to create a universal approach to prevent exposures have faced several barriers, such as demographic, belief, language, and educational diversity. Evidence from multiple qualitative studies [5, 18, 19] indicates the need for a multifaceted approach to prevention strategies for worker safety training and safe handling practices. The appropriate approach should be determined by collaboration of local and state stakeholders who can best tailor interventions to the needs within their geographic area. This customization is necessary because the releases of pesticides and agricultural chemicals vary by state, as do the demographics of the applicators and farm workers. An example of a tailored prevention approach from Utah is discussed below.

Utah

Each year, the Utah Department of Agriculture and Farming holds workshops called Utah Pesticide Applicator

Training. These workshops primarily target Utah licensed pesticide applicators working in agricultural establishments and government/university settings, but also include those working in lawn care, pest control, and landscaping. Continuing education credits are offered as an incentive for applicators to attend the workshop. Motivated by a 2007 HSEES-data finding of a pesticide applicator death from acute exposure to an algaecide, the Utah Department of Agriculture and Farming combined outreach efforts with the Utah HSEES program to prevent future exposures to, and injuries from, agricultural chemicals and pesticides. The Utah HSEES coordinator planned, piloted, and evaluated and then modified accordingly a presentation for the agricultural chemical applicators.

In 2008, Utah HSEES presented at six Utah Pesticide Applicator Training workshops; the total audience number was 513. The 60-min presentation included a discussion of pesticide toxicology, actual pesticide release scenarios in Utah, risk factors for pesticide-related injury, and prevention strategies. The presentation concluded with an interactive game for review and reinforcement of key messages. The game always sparked a discussion, questions, and sharing related experiences. On average, participants rated the workshop as 8.5 (scale of 1–10, with 10 being the most satisfied) for the level of satisfaction for the following areas: topic, speaker, location, and the overall workshop.

As a result of attending the workshop, applicators reported that they were more likely to follow labels, be more aware of personal protective equipment benefits, improve record keeping, use contamination and chemical cleanup information, be more careful when mixing and applying to reduce exposures, keep in mind laws and practices, properly store pesticides, calculate portions more accurately for proper concentration, and change and launder clothes more often. Proper planning, piloting, evaluating, and adapting prevention strategies as needed should be followed by other localities.

Limitations

The HSEES system was useful for collecting data regarding acute chemical releases and their associated public health impacts. However, there were limitations to the system. The HSEES system collected data in only 17 states during 2003–2007 so the results may not necessarily be representative of the entire USA. However, HSEES was the only federal hazardous substances release database designed specifically to assess and record the public health consequences of acute chemical events that existed during this time period. The number of releases of pesticide and agricultural chemicals is likely underestimated since some incidents may have been missed because they did not get reported to state environmental agencies or other notifying sources. Additionally, this analysis did not include events where other chemicals were released in addition to pesticide and agricultural chemicals. Therefore, some exposure incidents were not characterized.

Conclusion

Exposure to pesticides and agricultural chemicals as a result of unintentional releases in the USA is a problem that is largely undefined, but results of this analysis suggest that the problem is widespread. Agricultural farm workers and children are the groups most frequently injured. State and local agencies should implement properly planned, piloted, and evaluated prevention outreach programs that target farm workers' health beliefs and behaviors. These should be targeted to audiences at a local level, taking into account cultural and behavioral factors, such as language and literacy levels. Additionally, interventions should target physicians, employers, and transporters of agricultural chemicals. Physicians should be taught to recognize and report acute injuries related to pesticides and agricultural chemicals. Employers should be encouraged to adopt and promote safety policies such as hand washing stations in fields. Transporters should be taught methods for the safe transport of pesticides and agricultural chemicals. Integrated pest management should be implemented whenever possible.

Disclaimer The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the Agency for Toxic Substances and Disease Registry.

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