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Magnitude and characteristics of acute paraquat- and diquat-related illnesses in the US: 1998–2013

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A R T I C L E I N F O

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A B S T R A C T

Background: Paraquat and diquat are among the most commonly used herbicides in the world.
Objectives: Determine the magnitude, characteristics, and root causes for acute paraquat- and diquat-related illnesses in the US
Methods: Illnesses associated with paraquat or diquat exposure occurring from 1998 through 2011 were identified from the Sentinel Event Notification System for Occupational Risks (SENSOR)-Pesticides Program, the California Department of Pesticide Regulation (CDPR) Pesticide Illness Surveillance Program (PISP), and the Incident Data System (IDS). Cases identified by the National Poison Data System (NPDS) were reviewed for the years 1998–2003 and 2006–2013.
Results: A total of 300 paraquat- and 144 diquat-related acute illnesses were identified by SENSOR, PISP, and IDS. NPDS identified 693 paraquat- and 2128 diquat-related acute illnesses. In SENSOR/PISP/IDS, illnesses were commonly low severity (paraquat=41%; diquat=81%); however, SENSOR/PISP/IDS identified 24 deaths caused by paraquat and 5 deaths associated with diquat. Nineteen paraquat-related deaths were due to ingestion, seven of which were unintentional, often due to improper storage in beverage bottles. In SENSOR/PISP/IDS, paraquat and diquat-related acute illnesses were work-related in 68% (n=203) and 29% (n=42) of cases, respectively. When herbicide application site was known, the vast majority of acute paraquat-related illnesses (81%) arose from agricultural applications. Common root causes of illness were failure to use adequate personal protective equipment (PPE), application equipment failure, and spill/splash of herbicide.
Conclusions: Although the magnitude of acute paraquat/diquat-related illnesses was relatively low, several fatalities were identified. Many illnesses could be prevented through stricter compliance with label requirements (e.g. ensuring proper herbicide storage and PPE use), and through enhanced training of certified applicators.

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1. Introduction

Paraquat, a non-selective contact herbicide and desiccant, was first registered in the United States (US) in 1964. It is currently approved for use in nearly 90 countries and is one of the most commonly used herbicides worldwide (Paraquat Information Center, 2014). In the US, products containing paraquat are classified as "restricted use" pesticides due to their high toxicity, meaning they can only be purchased and used by certified applicators or by those working under their direct supervision (USEPA, 1997). The lethal dose (LD_{50}) of paraquat in humans is 20–40 mg ion/kg of body weight, which is 1.2–2.4 US teaspoons of a paraquat product with a 30% concentration (Vale et al., 1987). Contact with paraquat via inhalation, ingestion, ocular, or skin routes of exposure can cause severe health effects including pulmonary fibrosis, pulmonary edema, erythema, dermatitis, ulceration of the mouth, and brain damage (Roberts and Reigert, 2013). Given its strong irritant properties, handlers (i.e. mixers, loaders, and applicators) are required to take precautions to prevent skin and eye exposure and to prevent splashes into the mouth by adopting engineering controls or using personal protective equipment (PPE) including chemical resistant gloves, eye protection, and an air-purifying respirator (USEPA, 1997). In California, a closed system is required when mixing and loading paraquat (closed systems are devices designed to prohibit the escape of the pesticide outside the system, thereby preventing exposure to a handler). Due to its high toxicity, paraquat has not been approved for use in the European Union since 2007 (The Court of First Instance Annuls, 2007) and is banned or not registered in at least seven other countries (Watts, 2011).

Diquat dibromide, like paraquat, is in the dipyridyl chemical class and is also a non-selective contact herbicide and desiccant that was first registered for use in the US in 1986 (Roberts and Riegert, 2013). With an oral LD_{50} of 231 mg/kg in rats, diquat is considered to be less toxic than paraquat (the oral paraquat LD_{50} is 150 mg/kg in rats) (WHO, 2005). Products containing diquat are not classified as restricted use and are available for purchase to non-professionals (USEPA, 1995). Exposure to diquat causes corrosive effects to tissue, including the skin and gastrointestinal tract (Jones and Vale, 2000). Systemic toxicity, including kidney failure and central nervous system toxicity, is usually associated with diquat ingestion. Unlike paraquat, diquat is not selectively concentrated in the lung (Rose and Smith, 1977) and is not known to directly cause pulmonary fibrosis (Vanholder et al., 1981; Jones and Vale, 2000).

Despite their high toxicity and availability for purchase over multiple decades, little information on the magnitude, characteristics, and root causes for acute paraquat and diquat-related illnesses in the US is available. The purpose of this study is to address this gap.

2. Methods

2.1. Data sources

Data from three systems were combined to identify cases of acute paraquat and diquat-related illnesses and to assess their characteristics and root causes: the National Institute for Occupational Safety and Health (NIOSH) Sentinel Event Notification System for Occupational Risks (SENSOR)-Pesticides Program; the California Department of Pesticide Regulation (CDPR) Pesticide Illness Surveillance Program (PISP); and, the US Environmental Protection Agency (EPA), Office of Pesticide Programs' (OPP) Incident Data System (IDS). In addition, data from a fourth separate system that is national in scope were also assessed: the National Poison Data System (NPDS) maintained by the American Association of Poison Control Centers (AAPCC). Because few details were available on NPDS cases, they were not cross-referenced with cases from the other three data sources. As such, NPDS data were used only to assess the national magnitude and trend of acute paraquat- and diquat-related illness. Given the likely overlap in cases between NPDS and the other data systems, NPDS findings should be considered separately and not be combined with data from the other three systems. Because all personal identifiers were removed from the data prior to NIOSH submission, this study was exempt from consideration by the federal Institutional Review Board.

The SENSOR-Pesticides program has collected pesticide poisoning data from state health departments using standardized definitions and variables since 1998 (Calvert et al., 2008). Data for this study were provided by the following 11 states: California Department of Public Health (CDPH) (1998–2011), Florida Department of Health (1998–2011), Iowa Department of Public Health (2006–2011), Louisiana Department of Health and Hospitals (2000–2011), Michigan Department of Community Health (2000–2011), New Mexico Department of Health (2005–2008), New York State Department of Health (1998–2011), North Carolina Department of Health and Human Services (2007 –2011), Oregon Department of Human Services (1998–2011), Texas Department of State Health Services (1998–2011), and Washington State Department of Health (2001–2011).

In California, two programs identify cases of acute pesticide-related illness/injury: CDPH, a SENSOR-Pesticides participant; and, the Pesticide Illness Surveillance Program (PISP), which is administered by the California Department of Pesticide Regulation (CDPR). PISP operates similarly to the SENSOR-Pesticides program, but there are differences in the case definition and the variables used to characterize cases. PISP does not formally participate in the SENSOR-Pesticides program, but collaborates on joint activities (e.g. manuscripts) (Calvert et al., 2010). CDPH collects only work-related cases, while PISP collects data for both work-related and non-work-related acute pesticide-related illness/injury. An illness is considered work-related if the pesticide exposure occurred at the case's place of work. To ensure California cases were counted only once, CDPH cross-referenced its cases with those from PISP using name, date of illness/injury, social security number and date of birth. A total of 28 California cases were identified by both programs and counted only once. All other SENSOR-Pesticides states collect data on both work-related and non-work-related acute pesticide-related illness/injury, except New Mexico and Iowa (only work-related cases).

SENSOR-Pesticides and PISP case ascertainment sources primarily are poison control centers (PCC), other government agencies (such as a state's Department of Agriculture), workers' compensation documents, and physician reports. Staff from state surveillance programs attempt to interview cases and review medical records, and use standardized variables to systematically code all information about a case (CDC, 2005).

IDS began in 1992 and is a national database of alleged or anecdotal human health incidents. Under FIFRA Section 6a2, pesticide registrants are required to submit all eligible incident reports they receive to EPA. Incident reports are submitted primarily by pesticide registrants, but some are also submitted by other sources such as government and non-governmental organizations (USEPA, 2007). For this report, fatal, high, and moderate severity paraquat incidents reported in IDS between 1998 and 2011 were identified and included. IDS data for diquat were unavailable for this paper because they were under review in the EPA reregistration process. NIOSH used information from IDS reports to populate SENSOR-Pesticides variables. To ensure IDS cases were counted only once, IDS cases were cross-referenced with those from SENSOR-