



Household cleaning product-related ocular exposures reported to the United States poison control centres

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Abstract

Background/objectives To investigate ocular exposures associated with household cleaning products in the United States. **Subjects/methods** A retrospective analysis of ocular exposures associated with household cleaning products was conducted using data from the National Poison Data System from 2000 through 2016.

Results From January 2000 through December 2016, poison control centres in the United States received 319,508 calls for household cleaning product-related ocular exposures, averaging 18,795 exposures annually. The annual frequency of exposures decreased significantly by 28.8% during the study period. The rate of exposures per 100,000 US residents was 28.4 among young children (<6 years), 4.8 among older children (6–12 years), 4.2 among teenagers (13–19 years), and 4.2 among adults (≥20 years); children 2 years old had the highest rate of exposure (62.8). Bleaches (25.9%), wall/floor/tile cleaners (13.4%), disinfectants (10.8%), laundry detergents (6.1%), and glass cleaners (5.3%) were the non-miscellaneous product subcategories most commonly associated with ocular exposures. The product subcategories associated with the greatest proportion of major medical outcomes were drain cleaners (1.4%), oven cleaners (1.1%), and automatic dishwasher detergents (0.4%).

Conclusions On average, the United States poison control centres received approximately two reports of household cleaning product-related ocular exposures every hour during the 17-year study period. Although the annual number and rate of exposures declined during this time, the number of these exposures remains high, especially among young children, underscoring the need for additional prevention efforts. Contrary to the overall trend, ocular exposures to laundry detergent packets have increased significantly and merit special preventive action.

Introduction

Household cleaning products represent a major source of exposures reported to the United States (US) poison control centres (PCCs). These cleaning substances have ranked among the top three substance classes associated with

poisoning exposures since 2000. Since then, they have been linked to more than 190,000 cases reported to PCCs nationwide annually [1].

Exposures to household cleaning products commonly involve the eyes. In a study of exposures linked to cleaning products, 8.4% occurred as a result of eye contact [2]. Among children, this proportion may be even higher, with one investigation of paediatric cleaning product-related injuries citing eyes as the injured body region in nearly one-fourth of cases [3, 4]. Ocular exposures to household cleaning products are associated with a wide spectrum of clinical effects, including eye pain, conjunctivitis, abnormal vision, chemical burns, and corneal ulcerations [2].

While previous research has broadly investigated injuries linked to cleaning agents and exposures to specific substances such as laundry detergent packets [2, 3, 5, 6], to our knowledge, this is the first comprehensive analysis of the US PCC data regarding eye exposures associated with household cleaning products.

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Subjects and methods

Data source

There are currently 55 regional PCCs that receive calls regarding substance exposures in the US, District of Columbia, and the US territories. These centres offer free, expert medical advice through the Poison Help Line 24 h per day, seven days a week. When responding to PCC calls, poison specialists document clinical findings associated with each case during consultation with the physician, patient, or patient's guardian. A subset of this information, which includes 131 clinical effects organized by organ system, is uploaded to the NPDS. Clinical effects listed under the "ocular" category include blurred vision, burns, corneal abrasion, irritation/pain, lacrimation, miosis, mydriasis, nystagmus, papilledema, photophobia, pupil(s) nonreactive, red eye/conjunctivitis, and visual defect. For each clinical effect, PCC specialists determine whether the effect is "related", "not related," or "unknown if related" to the exposure to the reported substance. Clinical effects are deemed "related" when the: "timing of the effect is reasonable for the reported exposure; severity of the effect is consistent with the reported exposure; effect is consistent with the anticipated substance toxicity; (or) clinical assessment of the relationship was made by a physician" [7]. When possible, PCC specialists continue to follow cases until the severity and duration of effects and outcomes are known, which may include throughout the course of the patient's hospitalization. Upon the completion of follow-up, PCC specialists classify cases into the medical outcome categories: no effect, minor effect, moderate effect, major effect, or death.

Data from exposures reported to PCCs are uploaded in near-real-time to the National Poison Data System (NPDS), a database maintained by the American Association of Poison Control Centers (AAPCC) that follows strict data quality control guidelines [7, 8]. This investigation retrospectively analysed ocular exposures associated with household cleaning products in the 50 US states and district of Columbia reported to the NPDS from January 1, 2000 through December 31, 2016.

Case selection criteria

NPDS data were obtained for all single-substance ocular exposures involving the major substance category of "cleaning substances (household)" from January 1, 2000 through December 31, 2016. The following were exclusion criteria for this study: (1) calls that originated outside the 50 US states or the District of Columbia ($n = 2006$); (2) medical outcomes categorized as confirmed non-exposure or unrelated effect ($n = 1000$); (3) reason for exposure documented as bite or sting, food poisoning, abuse,

suspected suicide, adverse reaction to food, or withdrawal ($n = 101$); and (4) level of care coded as admitted to a psychiatric facility ($n = 32$). A total of 319,508 cases were included in study analyses.

Study variables

Study variables from the NPDS database included patient age and sex, product subcategory, year of exposure, state and site where exposure occurred, management site, level of health care received, medical outcome, clinical effects, and therapies.

Individuals were categorized as young children (<6 years), older children (6–12 years), teenagers (13–19 years), and adults (≥ 20 years). States were grouped into regions (Northeast, Midwest, South, and West) as defined by the US Census Bureau [9]. Exposure sites were classified as residence (including patient's own residence and other residence), workplace, other (including health care facility (HCF), school, restaurant/food service, public area, and other), and unknown. The following AAPCC definitions of medical outcome were used: minor effect (symptoms are typically rapidly resolving and minimally bothersome); moderate effect (symptoms are more pronounced, prolonged, or systemic in nature than minor effect and usually necessitate some form of treatment); major effect (symptoms are life-threatening or result in significant residual disability or disfigurement) [7].

Statistical analysis and ethical statement

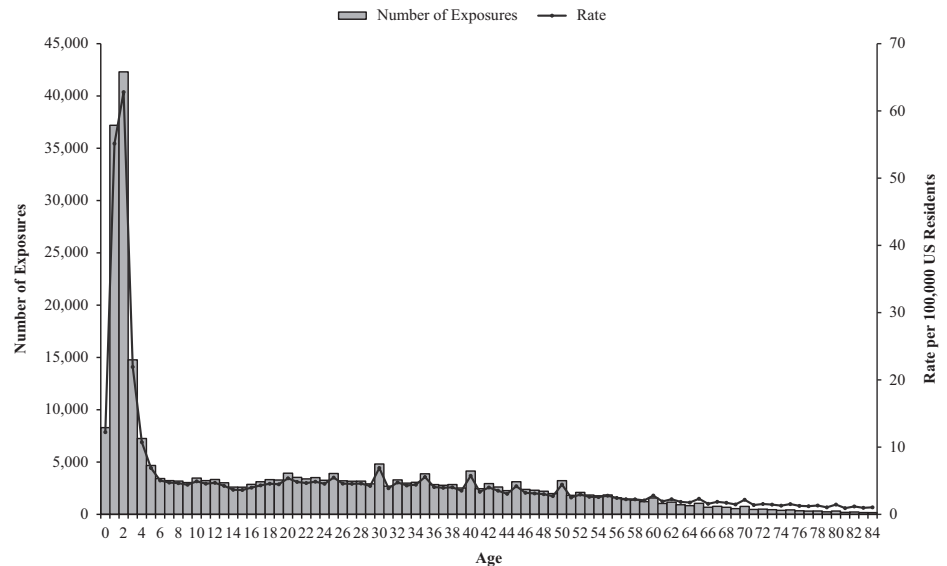
Statistical analysis was conducted using SPSS 21.0 (IBM Corp, Armonk, NY) and SAS 9.4 (SAS Institute, Inc., Cary, NC) software. Population-based rates were calculated using July 1st intercensal and postcensal population estimates for 2000–2016 from the US Census Bureau [10]. Linear and piecewise regression was used to analyse secular trends, and the estimated slope (m) from the regression model was reported, along with the associated p value. Statistical significance was determined at $\alpha = 0.05$. This study was judged exempt by the Institutional Review Board of the authors' institution.

Results

General characteristics

From January 2000 through December 2016, there were 319,508 calls to US PCCs regarding ocular exposures to household cleaning products, which equate to a mean of 18,795 exposures annually. The mean age of exposed individuals was 20.7 years (standard error of the mean =

Fig. 1 Number and rate of ocular exposures associated with household cleaning products by age, National Poison Data System 2000–2016. Exposures to individuals >84 years old are not shown because census data were not available for individuals >84 years old by single year of age; therefore, the rate per 100,000 US residents could not be calculated for individuals >84 years old



0.04). Adults (≥ 20 years) accounted for 49.1% of exposures, while young children (<6 years of age), older children (6–12 years of age), and teenagers (13–19 years of age) accounted for 35.9%, 7.3%, and 6.6%, respectively. The rate of exposures per 100,000 US residents was highest for young children (28.4), followed by older children (4.8), teenagers (4.2), and adults (4.2). Children 2 years of age had the highest exposure rate (62.8) (Fig. 1).

Approximately two-thirds (67.1%) of exposures among adults involved females (Table 1). Conversely, males accounted for the majority of exposures among young children (61.3%), older children (53.5%), and teenagers (52.5%). Most exposures occurred in residences (86.3%), followed by workplaces (8.8%), and schools (3.3%). Most exposures were unintentional (98.7%) and involved liquids (59.0%) or aerosols/sprays (18.3%). The Southern region of the US accounted for more exposures (36.9%) than other regions. Key study variables demonstrated minor variation by region; for example, the range in percentages by region was 52.9–55.2% for female sex, 47.4–51.6% for adults >20 years old, 83.4–87.2% for exposures occurring in residences, 0.1–0.6% for admissions to a HCF, 5.5–9.0% for moderate effect, and 0.1–0.2% for major effect. The top three product categories accounted for a similar percentage of all ocular exposures in each region: 22.2–29.5% for bleaches, 13.0–13.8% for wall/floor/tile cleaners, and 9.7–11.4% for disinfectants.

Medical outcome, clinical effects, and management

Approximately one-third (34.4%) of exposures were not followed until the medical outcome could be established with reasonable certainty, including 28.9% that were judged as nontoxic exposures or exposures with minimal clinical

effects possible and 5.4% that were lost to follow-up. Among exposures that were followed to a known medical outcome, 6.4% resulted in no effects, 81.5% in minor effects, 11.9% in moderate effects, and 0.2% in major effects. Adults experienced the highest proportions of moderate (10.4%) and major (0.2%) effects. There were 398,879 related ocular clinical effects (some individuals had more than one clinical effect), and the most commonly reported ocular effects were ocular irritation or pain (62.7%), red eye or conjunctivitis (23.7%), lacrimation (5.0%), blurred vision (3.4%), and corneal abrasion (2.8%).

Most (61.4%) exposed individuals were managed on-site, while 36.6% were already in/en route to a HCF or referred to a HCF by the PCC (Table 1). Overall, 63.6% of exposures did not receive care at a HCF, 28.1% were treated/evaluated and released from a HCF, and 0.3% were admitted to a HCF. A greater proportion (32.9%) of adults was treated/evaluated and released than other age groups. The therapies utilized most frequently were dilution/irrigation/wash (92.0%) and antibiotics (4.6%).

Product subcategories

The product subcategory of bleaches was most commonly associated with ocular exposures, accounting for approximately one-fourth of exposures (25.9%) (Table 2). Other non-miscellaneous product subcategories commonly associated with exposures included wall/floor/tile cleaners (13.4%), disinfectants (10.8%), laundry detergents (6.1%), glass cleaners (5.3%), and toilet bowl cleaners (4.7%). Although bleaches represented the most common product subcategory among individuals 6 years of age and older, wall/floor/tile cleaners were most frequently (18.9%) associated with exposures among young children.

Table 1 Characteristics of ocular exposures associated with household cleaning products by age group, National Poison Data System 2000–2016

Characteristics	Age group (years)				Total ^a n (%) ^b
	<6 n (%) ^b	6–12 n (%) ^b	13–19 n (%) ^b	≥20 n (%) ^b	
Sex					
Female	44,359 (38.7)	10,746 (46.5)	10,073 (47.5)	105,118 (67.1)	172,046 (54.0)
Male	70,395 (61.3)	12,358 (53.5)	11,129 (52.5)	51,596 (32.9)	146,576 (46.0)
Unknown	217	72	24	247	886
Exposure site					
Residence ^d	112,996 (98.4)	16,419 (71.0)	14,047 (66.6)	128,569 (82.4)	274,478 (86.3)
Workplace	97 (0.1)	37 (0.2)	3234 (15.3)	24,335 (15.6)	28,045 (8.8)
School	733 (0.6)	6132 (26.5)	3080 (14.6)	455 (0.3)	10,505 (3.3)
Other ^e	982 (0.9)	547 (2.4)	719 (3.4)	2621 (1.7)	5007 (1.6)
Unknown	163	41	146	981	1473
Management site					
Managed on-site (non-HCF)	81,058 (70.9)	15,791 (68.5)	11,985 (56.9)	83,945 (54.0)	194,490 (61.4)
Patient already in/en route to HCF	20,334 (17.8)	3079 (13.4)	4654 (22.1)	39,865 (25.6)	68,598 (21.6)
Patient was referred by PCC to a HCF	12,153 (10.6)	2400 (10.4)	3349 (15.9)	29,245 (18.8)	47,600 (15.0)
Other	799 (0.7)	1781 (7.7)	1059 (5.0)	2442 (1.6)	6163 (1.9)
Unknown	627	125	179	1464	2657
Level of health care received					
No HCF care received	82,484 (71.7)	17,697 (76.4)	13,223 (62.3)	87,850 (56.0)	203,309 (63.6)
Treated/evaluated and released	26,970 (23.5)	4324 (18.7)	6179 (29.1)	51,581 (32.9)	89,715 (28.1)
Admitted ^f	343 (0.3)	47 (0.2)	64 (0.3)	528 (0.3)	1003 (0.3)
Other ^g	5174 (4.5)	1108 (4.8)	1760 (8.3)	17,002 (10.8)	25,481 (8.0)
Medical outcome					
No effect	7809 (6.8)	1047 (4.5)	580 (2.7)	3,752 (2.4)	13,343 (4.2)
Minor effect	65,503 (57.0)	13,060 (56.4)	11,655 (54.9)	79,384 (50.6)	170,868 (53.5)
Moderate effect	5744 (5.0)	1058 (4.6)	1604 (7.6)	16,334 (10.4)	24,932 (7.8)
Major effect	147 (0.1)	23 (0.1)	18 (0.1)	295 (0.2)	490 (0.2)
Not followed (minimal clinical effects possible) ^h	31,878 (27.7)	7274 (31.4)	6172 (29.1)	46,183 (29.4)	92,582 (29.0)
Unable to follow, judged as a potentially toxic exposure	3,890 (3.4)	714 (3.1)	1197 (5.6)	11,013 (7.0)	17,293 (5.4)
Total (row %)^c	114,971 (36.0)	23,176 (7.3)	21,226 (6.6)	156,961 (49.1)	319,508 (100.0)

^aTotal includes individuals with age group unknown

^bColumn percentages may not sum to 100.0% due to rounding error

^cRow percentages may not sum to 100.0% due to rounding error

^dIncludes “own residence” and “other residence”

^eOther includes “HCF,” “restaurant/food service,” “public area,” and “other”

^fAdmitted includes “admitted to critical care unit” and “admitted to noncritical care unit”

^gOther includes “patient refused referral/did not arrive at HCF” and “patient lost to follow-up/left against medical advice”

^hNot followed (minimal clinical effects possible) includes “not followed (minimal clinical effects possible)” and “not followed, judged as nontoxic exposure”

Among all exposures followed to known medical outcomes, the product subcategories with the highest proportion of major effects were drain cleaners (1.4%), oven cleaners (1.1%), and automatic dishwasher detergents (0.4%). Likewise, the product subcategories with the greatest proportion of moderate effects were oven

cleaners (29.3%), drain cleaners (26.3%), and rust removers (19.2%). In addition, the product subcategories with the highest proportion of minor effects were hand dishwashing products (85.6%), bleaches (84.2%), and fabric softeners/antistatic agents (83.7%) (Table 2).

Table 2 Ocular exposures associated with household cleaning products by product subcategory and medical outcome, National Poison Data System 2000–2016

Product subcategories/generic product names ^b	Total ^a <i>n</i> (col. %) ^c	Exposures followed to known medical outcomes			
		No effect <i>n</i> (row %) ^d	Minor effect <i>n</i> (row %) ^d	Moderate effect <i>n</i> (row %) ^d	Major effect <i>n</i> (row %) ^d
Bleaches	82,599 (25.9)	2222 (4.3)	43,651 (84.2)	5893 (11.4)	64 (0.1)
Hypochlorite (liquid and dry)	80,153 (25.1)	2127 (2.7)	42,390 (52.9)	5720 (7.1)	58 (0.1)
Miscellaneous Cleaners	48,146 (15.1)	2186 (6.9)	25,436 (80.0)	4100 (12.9)	87 (0.3)
Miscellaneous cleaning agents: alkalis	13,278 (4.2)	568 (4.3)	7049 (53.1)	1593 (12.0)	43 (0.3)
Miscellaneous cleaning agents: anionics or nonionics	8689 (2.7)	361 (4.2)	4690 (54.0)	592 (6.8)	17 (0.2)
Miscellaneous cleaning agents: cationics	6152 (1.9)	195 (3.2)	3034 (49.3)	771 (12.5)	15 (0.2)
Miscellaneous cleaning agents: isopropanol (excluding automotive products and glass)	5831 (1.8)	323 (5.5)	3051 (52.3)	156 (2.7)	1 (0.0)
Miscellaneous cleaning agents: other or unknown household cleaning agents	7987 (2.5)	434 (5.4)	4245 (53.1)	579 (7.2)	10 (0.1)
Wall/floor/tile cleaners	42,841 (13.4)	2343 (8.1)	23,498 (81.3)	2990 (10.3)	64 (0.2)
Wall/floor/tile/all-purpose Cleaning agents: acids	7717 (2.4)	437 (5.7)	4609 (59.7)	517 (6.7)	13 (0.2)
Wall/floor/tile/all-purpose cleaning agents: alkalis	17,953 (5.6)	961 (5.4)	9651 (53.8)	1404 (7.8)	33 (0.2)
Wall/floor/tile/all-purpose cleaning agents: anionics or nonionics	6616 (2.1)	329 (5.0)	3530 (53.4)	546 (8.3)	5 (0.1)
Wall/floor/tile/all-purpose cleaning agents: cationics	4680 (1.5)	236 (5.0)	2427 (51.9)	218 (4.7)	4 (0.1)
Disinfectants	34,591 (10.8)	1,508 (6.9)	18,174 (82.7)	2263 (10.3)	41 (0.2)
Disinfectants: hypochlorite (non-bleach products)	13,820 (4.3)	395 (2.9)	6749 (48.8)	1207 (8.7)	20 (0.1)
Disinfectants: other or unknown	14,273 (4.5)	781 (5.5)	7895 (55.3)	697 (4.9)	10 (0.1)
Disinfectants: phenol	3110 (1.0)	170 (5.5)	1763 (56.7)	145 (4.7)	7 (0.2)
Disinfectants: pine oil	3388 (1.1)	162 (4.8)	1767 (52.2)	214 (6.3)	4 (0.1)
Laundry detergents	19,338 (6.1)	440 (3.4)	10,398 (80.8)	1983 (15.4)	41 (0.3)
Laundry detergents: granules (various containers)	6258 (2.0)	173 (2.8)	3493 (55.8)	401 (6.4)	7 (0.1)
Laundry detergents: liquids (unit dose)	5020 (1.6)	94 (1.9)	2745 (54.7)	778 (15.5)	20 (0.4)
Laundry detergents: liquids (various containers)	7502 (2.3)	156 (2.1)	3854 (51.4)	737 (9.8)	13 (0.2)
Glass cleaners	16,825 (5.3)	1497 (13.7)	8961 (82.1)	452 (4.1)	4 (0.0)
Glass cleaners: ammonia containing	8833 (2.8)	880 (10.0)	4737 (53.6)	181 (2.0)	2 (0.0)
Glass cleaners: isopropanol	4894 (1.5)	363 (7.4)	2587 (52.9)	144 (2.9)	2 (0.0)
Toilet bowl cleaners	14,911 (4.7)	517 (4.7)	8937 (81.8)	1450 (13.3)	19 (0.2)
Toilet bowl cleaners: acids	8845 (2.8)	287 (3.2)	5665 (64.0)	932 (10.5)	10 (0.1)
Toilet bowl cleaners: alkalis	4082 (1.3)	148 (3.6)	2223 (54.5)	363 (8.9)	6 (0.1)
Laundry prewash/stain removers	13,324 (4.2)	681 (7.3)	7481 (80.5)	1103 (11.9)	23 (0.2)
Laundry prewash/stain removers: liquid surfactant based	4458 (1.4)	204 (4.6)	2406 (54.0)	491 (11.0)	10 (0.2)
Laundry prewash/stain removers: other or unknown	5665 (1.8)	303 (5.3)	3273 (57.8)	301 (5.3)	7 (0.1)
Miscellaneous cleaning substances (household)	9050 (2.8)	574 (9.7)	4879 (82.2)	468 (7.9)	11 (0.2)
Carpet, upholstery, leather, or vinyl cleaners	6326 (2.0)	8 (0.0)	3478 (1.1)	304 (0.1)	416 (0.1)
Hand dishwashing	7312 (2.3)	176 (3.8)	4013 (85.6)	491 (10.5)	7 (0.1)
Anionic or nonionic hand dishwashing detergents	5511 (1.7)	135 (2.4)	3091 (56.1)	369 (6.7)	7 (0.1)
Oven cleaners	5968 (1.9)	183 (4.4)	2691 (65.1)	1210 (29.3)	47 (1.1)
Oven cleaners: alkalis	5203 (1.6)	161 (3.1)	2358 (45.3)	1083 (20.8)	41 (0.8)
Cleasers	5712 (1.8)	287 (7.8)	2942 (79.5)	466 (12.6)	7 (0.2)
Other types/unknown household cleaners	3532 (1.1)	177 (5.0)	1762 (49.9)	330 (9.3)	6 (0.2)
Drain cleaners	5401 (1.7)	158 (4.3)	2474 (68.0)	957 (26.3)	50 (1.4)
Drain cleaners-alkalis	4009 (1.3)	104 (2.6)	1807 (45.1)	736 (18.4)	43 (1.1)
Automatic dishwasher detergents	5201 (1.6)	140 (4.1)	2782 (80.8)	505 (14.7)	14 (0.4)
Spot removers/dry cleaning agents	2820 (0.9)	149 (8.1)	1538 (83.2)	160 (8.7)	2 (0.1)
Laundry additives	2412 (0.8)	145 (9.1)	1324 (82.6)	128 (8.0)	5 (0.3)
Rust removers	1855 (0.6)	61 (4.5)	1033 (76.0)	261 (19.2)	4 (0.3)
Fabric softeners/antistatic agents	1202 (0.4)	76 (9.7)	656 (83.7)	52 (6.6)	0 (0.0)
Total	319,508 (100.0)	13,343 (6.4)	170,868 (81.5)	24,932 (11.9)	490 (0.2)

^aTotal includes exposures with medical outcomes of “not followed (minimal clinical effects possible)” and “unable to follow, judged as a potentially toxic exposure”

^bSelected generic products were included if they accounted for $\geq 1\%$ of all exposures

^cColumn percentages were calculated using the total number of exposures as the denominator

^dRow percentages for each product were calculated using only the total number of exposures followed to a known medical outcome

Secular trends

During the 17-year study period, the annual number and rate of ocular exposures decreased significantly by 28.8% ($m = -600.1$, $p < 0.001$) and 37.8% ($m = -0.25$, $p < 0.001$), respectively (Fig. 2). This decrease in the number and rate of exposures was consistent across all age groups except children <6 years old, with the largest decrease in the number of exposures observed among teenagers 13–19 years old (45.3% decrease, $m = -68.2$, $p < 0.001$), followed by older children 6–12 years old (42.9% decrease, $m = -65.7$, $p < 0.001$) and adults (25.9% decrease, $m = -265.0$, $p < 0.001$). Among children <6 years old, the number of exposures decreased significantly from 2000 to 2011 (41.6% decrease, $m = -330.8$, $p < 0.001$) prior to a significant increase of 27.8% from 2011 to 2016 ($m = 230.0$, $p = 0.001$). Secular trends for study variables were similar among regions, with the exception of the number of

admissions to a HCF. For this variable, the Southern region, when compared with other regions, demonstrated a large increase during the study period; however, the annual number of admissions was relatively small.

Most product subcategories exhibited statistically significant decreases in exposure frequency from 2000 to 2016. Among these, the non-miscellaneous product subcategories that exhibited the greatest decreases were glass cleaners (76.9% decrease, $m = -92.6$, $p < 0.001$), spot removers (65.2% decrease, $m = -11.7$, $p < 0.001$), and oven cleaners (32.4% decrease, $m = -10.8$, $p < 0.001$). Exposures associated with wall/floor/tile cleaners increased by 28.0% from 2000 to 2004 ($m = 49.3$, $p = 0.453$) before decreasing significantly by 48.6% ($m = -139.4$, $p < 0.001$) from 2004 to 2016. The trend for laundry detergent exposures was downward from 2000 to 2011 (41.7% decrease, $m = -31.2$, $p = 0.004$) before an increase of 287.1% ($m = 374.5$, $p < 0.001$) from 2011 to 2016 (Fig. 3). This

Fig. 2 Rate of ocular exposures associated with household cleaning products by age group and by year, National Poison Data System 2000–2016

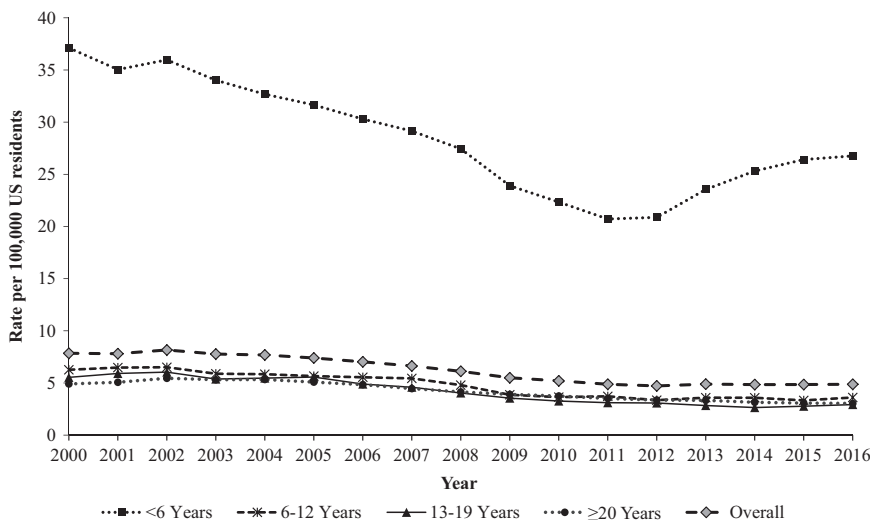
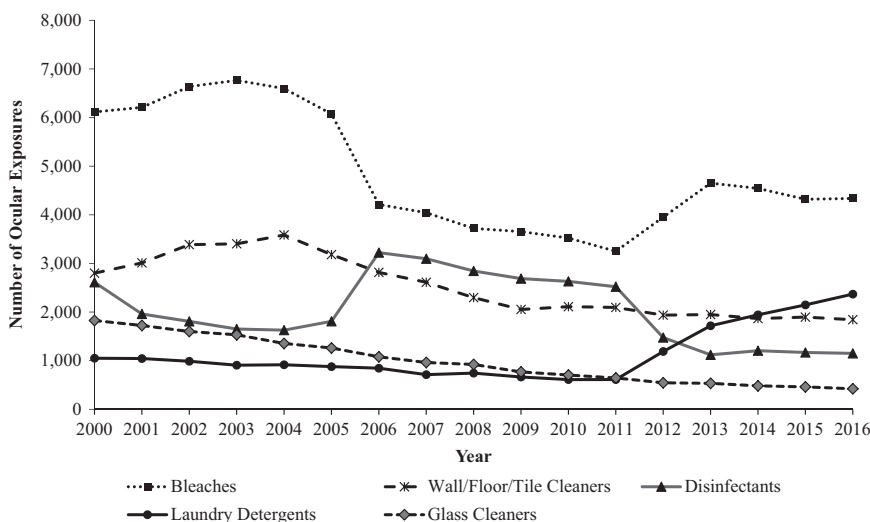


Fig. 3 Number of ocular exposures associated with the five household cleaning products most commonly associated with ocular exposure by year, National Poison Data System 2000–2016



represented an overall increase of 125.6% between 2000 and 2016, which is contrary to the decreasing trend seen for most product subcategories. This increase was mainly driven by laundry detergent packet-related ocular exposures, which increased significantly by 1959.7% ($m = 415.2$, $p < 0.001$) from 2012 to 2016; the number of exposures associated with other types of laundry detergents remained relatively constant ($m = 20.4$, $p = 0.532$) during that period. The secular trends in the annual number of ocular exposures for the five most commonly associated household cleaning products are shown in Fig. 3.

Discussion

Household cleaning products resulted in an average of almost 19,000 ocular exposures reported to the US PCCs annually, or about two exposures per hour. The annual number of exposures decreased significantly by 28.8% from 2000 through 2016, which is consistent with previous reports of exposures to household cleaning products as well as studies of eye injuries [3, 11, 12]. The Poison Prevention Packaging Act of 1970, which requires child-resistant packaging for a variety of household substances, has played an important role in the decline in paediatric poisoning during the decades that followed its enactment [13]. Under this law, child-resistant closures are mandated for many hazardous cleaning products, such as furniture polish, drain cleaners, oven cleaners, and rust removers. More recent advances in prevention practices and increased public awareness about the hazards of household cleaning substances may have contributed to the observed decrease in ocular exposures.

Despite these efforts, young children continue to be the age group with the highest rate of ocular exposure to household cleaning substances. In this study, children 2 years of age experienced the highest rate of exposure. A number of factors likely contribute to exposure risk at this age, including a large amount of time spent in the home, newfound mobility, curiosity for unfamiliar and intriguing external stimuli, and an inability to recognize potential danger [14]. Cleaning products may be particularly alluring to young children due to their colourful packaging and contents as well as unique scents. Access to these products may occur when child-resistant closures are inadequately sealed, container integrity is compromised from repeated use, or containers are stored in an unsafe manner [15]. A study of poisoning exposures among 11–18 month-old toddlers revealed that the proportion of cleaning substances stored unsafely—defined in the study as not stored in a locked cupboard or at adult eye level or above—was 27.9%, 15.0%, and 11.4% in the kitchen, bathroom, and garage or shed, respectively. Households with only one child or a

child who was not yet able to walk independently had a higher likelihood of unsafe storage practices [16].

The product subcategory most frequently associated with ocular exposures was bleaches, accounting for approximately one-fourth of exposures in this study. This finding is concordant with other studies that identify bleach as the most commonly implicated household cleaning product in paediatric ingestions [3, 17]. Other product subcategories commonly implicated in this study were wall/floor/tile cleaners, disinfectants, laundry detergents, glass cleaners, and toilet bowl cleaners. The high frequency of exposures linked to these substances may, in part, be attributed to their prevalence in the home and their accompanying storage strategies. For example, a prior study of households in which a child younger than 5 years resided noted disinfectants/antiseptic agents and bleaches to be present in 90 and 75% of homes, respectively [18]. Moreover, among a list of hazardous household substances, bleach and toilet bowl cleaners were observed to be among the least likely to be stored safely. Finally, perceived toxicity of specific products by parents may influence poison prevention practices and care-seeking behaviours in the event of a child exposure [19].

Since their introduction into the US market in 2012, laundry detergent packets have been associated with a plethora of unintentional poisoning exposures and have gained additional notoriety for their recent association with the social media phenomenon known as the “Tide Pod Challenge” [20–22]. Young children, in particular, may rupture the packets, resulting in ingestions as well as dermal and ocular exposures. From 2012 through 2013, PCCs nationwide received more than 17,000 reports of laundry detergent packet exposures among children <6 years of age. Among the spectrum of associated clinical effects, the most commonly observed ocular sequelae included irritation or pain, red eye or conjunctivitis, lacrimation, corneal abrasion, and burns [5]. In our study, the product subcategory of laundry detergents was the only one that exhibited a statistically significant overall increase in exposure frequency, with this increase starting in 2012. While the number of laundry detergent packet-related ocular exposures increased from 2012 through 2016, the number associated with other types of laundry detergents remained relatively constant, emphasizing the urgent need to increase prevention efforts that target laundry detergent packets.

The product subcategories associated with the greatest proportion of major effects were drain cleaners and oven cleaners. Drain cleaners and oven cleaners typically have pH values of 12 or higher; the presence of a strong base, often sodium hydroxide, in these substances facilitates the disruption of bonds in oil or grease of animal and plant origin [23]. Due to their alkaline nature, these substances are able to penetrate ocular tissues more rapidly and deeply

than acids and may cause significant damage to the cornea, iris, ciliary body, and lens [24–26]. Sequelae of chemical eye exposures may be severe, with the potential for significant visual impairment or disfigurement.

Prevention

Prevention efforts should be prioritized for children <6 years of age because this age group has an ocular exposure rate to household cleaning products that is more than 6 times higher than that of other age groups. Utilization of child-resistant containers, safe storage of potentially hazardous products in locations that are out of the reach and sight of young children, and caution when using these products around young children are useful strategies to prevent unintentional ocular exposures as well as ingestions in this age group. Increased adoption of flow resistors on liquid containers may have a role in limiting eye exposures and ingestions. Improved burst resistance and individual wrapping of laundry detergent packets may help prevent ocular exposure to the contents of these products. Increased public awareness about risks to ocular health as well as prevention and treatment options may help reduce the frequency and associated morbidity of ocular exposures. Manufacturer participation is crucial to ensure the integrity and effectiveness of child-resistant closures, pursue reformulation of products (when possible) to reduce the hazard, and modify packaging to decrease attractiveness to young children. Finally, ongoing involvement of health professionals, policy makers, and others is essential to promote the continued decline in ocular exposures associated with household cleaning products.

Study limitations

This study underestimates the actual number of ocular exposures associated with household cleaning products in the US because NPDS data are voluntarily reported. As a result, this database does not include exposures that did not result in a call to a PCC for reasons such as lack of awareness of PCC resources, failure to seek care, or receipt of medical care directly from a HCF or other provider without a call to a PCC. However, previous research showed that the reported number of paediatric pharmaceutical ingestion cases was similar for the NPDS and a national emergency department surveillance system, which supports the validity of NPDS data [27]. Although PCC professionals adhere to strict protocols for following and documenting exposures, the accuracy and completeness of the information included in the NPDS cannot be fully verified by PCCs or the AAPCC. Imprecision may also arise from miscoding by PCC specialists. Despite these limitations, the NPDS is a high-quality national data source for

the investigation of ocular exposures associated with household cleaning substances in the US.

Summary

What was known before

- Exposure to household cleaning products commonly involves the eyes, especially among children.
- Ocular exposures to household cleaning products are associated with a wide spectrum of clinical effects.

What this study adds

- From January 2000 through December 2016, poison control centres in the United States received 319,508 calls for household cleaning product-related ocular exposures, averaging 18,795 exposures annually. Children 2 years of age had the highest rate of exposure (62.8 exposures per 100,000 United States residents).
- The annual frequency of ocular exposures to household cleaning products decreased significantly by 28.8% from 2000 to 2016; however, contrary to this overall trend, ocular exposures to laundry detergent packets increased significantly by 1960% from 2012 to 2016.
- Product subcategories associated with the greatest proportion of major medical outcomes were drain cleaners, oven cleaners, and automatic dishwasher detergents.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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