Cleaning Products and Work-Related Asthma, 10 Year Update

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Objective: To describe the frequency of work-related asthma (WRA) and characteristics of individuals with exposure to cleaning products 1998 to 2012, compared with 1993 to 1997. **Methods:** Cases of WRA from products used for cleaning or disinfecting surfaces were identified from California, Massachusetts, Michigan (1998 to 2012), New Jersey (1998 to 2011), and New York (2009 to 2012). **Results:** There were 1199 (12.4%) cleaning product cases among all 9667 WRA cases; 77.8% women, 62.1% white non-Hispanic, and average age of 43 years. The highest percentages worked in healthcare (41.1%), and were building cleaners (20.3%), or registered nurses (14.1%). **Conclusions:** The percentage of WRA cases from exposure to cleaning products from 1998 to 2012 was unchanged from 1993 to 1997 indicating that continued and additional prevention efforts are needed to reduce unnecessary use, identify safer products, and implement safer work processes.

Keywords: asthma, cleaning products, disinfectants, surveillance

In 2003, the four states that tracked work-related asthma (WRA) in the United States published their surveillance data related to cleaning products for 1993 through 1997. The data showed that 12% of the confirmed cases of WRA identified in California (CA), Massachusetts (MA), Michigan (MI), and New Jersey (NJ) were associated with exposure to cleaning products at work.[1] Since that time, there have been multiple publications expanding our understanding of the association between cleaning products and asthma. These publications have included cross-sectional and longitudinal studies, case reports, and exposure analyses.[2–6] Specific respiratory allergens have been identified in cleaning products.[7–12] Studies have identified an increased risk of developing asthma with both the frequency of use and the method of application (eg, as a spray vs as a wipe) of cleaning agents.[13] The increased use of disinfectants as part of building maintenance has led to best practice recommendations to use them only when necessary, for example, in situations where they are proven to reduce the occurrence of infectious diseases or when required by regulations. One reason for these best practice recommendations is to reduce the risk of WRA from exposure to disinfectants.[14]

In this paper, we present an update on the occurrence of WRA associated with cleaning products from five states (original four plusNew York) in the United States that conducted surveillance for WRA after 1997.

METHODS

All five surveillance systems were based on healthcare providers diagnosing a patient with WRA. MA, MI, NJ, and New York (NY) mandate that WRA cases be reported to the state and these reports were actively solicited. In CA, the physician reports were part of a mandatory reporting requirement linked to physician reimbursement for medical services. The methodology used in this update by CA, MA, MI, and NJ is similar to that used in the previous publication.[1] However, this update includes data from NY, as well as new sources added by CA, MA, MI, and NJ to identify potential cases of WRA. The multiple sources used included healthcare provider reports (all states), emergency department (ED) or hospital discharge (HD) data (all states), and workers' compensation (WC) data (CA, MA, MI, NY). There were differences in how the states used ED, HD, and WC data to identify cases. MI, NJ, and NY reviewed all HD and ED medical records with International Classification of Diseases, Ninth Revision (ICD-9) codes 506.0 to 506.9 (respiratory conditions due to chemical fumes and vapors) regardless of payer or ICD-9 codes 493.0 to 493.9 (asthma) where workers' compensation was the primary expected payer to identify cases where there was a physician's diagnosis consistent with asthma associated with work. NJ also reviewed HD records with ICD-9 codes 786.2 (cough) and 786.9 (other symptoms involving respiratory system and chest) regardless of payer. MA reviewed all HD and ED records with ICD-9 codes 506.0 to 506.9, 493.0 to 493.9 or 786.09 (dyspnea) where workers' compensation was the expected payer or a V or E code or free text in the discharge data that indicated work. CA reviewed all ED and HD records with an ICD-9 code 493.0 to 493.9 where workers' compensation was the expected payer. CA, MI, MA, and NY identified additional WRA cases through their WC systems; CA reviewed all workers' compensation cases with an indicator of asthma either in a text field or with ICD-9 codes 493.0 to 493.9; MI and NY interviewed cases and obtained their medical records where the WC record indicated the lung as the body part; and MA reviewed cases with an indicator of asthma in the nature of illness or text description field.

The criteria for WRA case confirmation and classification have been previously published.[15] All five states used the same WRA case definition requiring a diagnosis consistent with asthma and an association with work. Data on confirmed cases of WRA were available from CA, MA, and MI for the years 1998 through 2012, from NJ for 1998 through 2011, and from NY for 2009 through 2012.

After potential cases were identified, standardized follow up questionnaires were administered by telephone in all five states to obtain additional information about workplace exposures associated

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Clinical Significance: Work-related asthma (WRA) from cleaning products continues to be a common cause of both new-onset and work aggravated asthma. Cleaning products are widely used and cases worked in all industry sectors. The highest percentage of cases worked in non-cleaning jobs (ie, nurses, office staff) in health care and education.

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with asthma symptoms, medical history, and non-occupational risk factors. For each case, up to three exposures (agents) were recorded as the possible cause of asthma symptoms. In addition, medical records were reviewed as part of the confirmation process. Based on the results from the interviews and medical record reviews, cases were confirmed as being work-related asthma and were further classified as: (1) work aggravated asthma if a person had physician-diagnosed asthma before beginning work and their asthma became worse at a particular job or (2) new-onset WRA.[15] New onset WRA cases were further classified as: (1) asthma without a latency period between exposure and disease (reactive airways dysfunction [RADS]) also known as acute irritant-induced asthma and (2) asthma that occurred after a period of exposure without symptoms (occupational asthma). A person was classified as having RADS if their asthma developed immediately after an acute exposure to an irritating chemical at work and symptoms lasted at least 3 months. A person was classified as having occupational asthma if their asthma developed after a period of exposure at work when they had no respiratory symptoms, their onset of respiratory symptoms was associated with work, and their symptoms then improved or were relieved when the patient was not working. Confirmed cases with insufficient information to distinguish whether the individual's asthma was work aggravated or new-onset were coded as ''confirmed, but unclassified.''

Occupational asthma cases were classified as having exposure to either a known or an unknown asthma inducer. The determination of whether a substance was a known asthma inducer was based on the Association of Occupational and Environmental Clinics (AOEC) exposure listing of substances that cause WRA.[16]

To identify cases with exposure to cleaning products, all cases of WRA ascertained during the years 1998 to 2012 were reviewed to identify those associated with cleaning products using similar methodology described in the previous publication for the 1993 to 1997 WRA cases.[1] All confirmed cases in which a cleaning product was reported by the case as being associated with their asthma were counted. A cleaning product was defined as a product or ingredient of a product used for cleaning and/or disinfecting surfaces in the general work environment. We excluded cases who were cleaning medical equipment or animals, cleaning in specialized industrial settings, or disinfecting pool water. Exposures may have occurred when workers used products to do cleaning tasks, when they were working near areas being cleaned by others, or after spills or improper mixing of cleaning products. We only included products, both water-based and solvent-based, used for cleaning or disinfecting surfaces (Appendix 1, http://links.lww.com/JOM/A672).

The overall number and percentage of confirmed WRA cases from 1998 to 2012 where a cleaning product was reported by a case were calculated. WRA cases associated with a cleaning product were also assessed by state, asthma classification, demographic characteristics, industry, and occupation. Industry was coded using the 2002 North American Industry Classification System and occupation was coded using the 2000 Standard Occupational Classification System.

The types of cleaning products and WRA classification in specified occupations for which cleaning was the primary activity were identified and compared with all other occupations. Cleaning occupations were defined as those with the following 2000 Standard Occupational Classification (SOC) codes: 37–1011 (first-line supervisors/managers of housekeeping and janitorial workers), 37–2010 (building cleaning workers), 37–2011 (janitors and cleaners, except maids and housekeeping cleaners), 37–2012 (maids and housekeeping cleaners), and 37–2019 (building cleaning workers, all other).

Results are presented including the data from NY, even though data from NY were not included in the prior manuscript on reports from 1993 to 1997.[1] All results were initially analyzed with and without data from NY included. Excluding the data from NY did not change the results, so to increase the geographic area covered and the number of cases, data from New York were included. All frequency counts, percentages, relative risks, and 95% confidence intervals (CI) were calculated using procedures in SAS® software version 9.4 (SAS Institute Inc., Cary, NC).

RESULTS

Table 1 shows the overall number and percentage of confirmed WRA cases where a cleaning product was reported as being associated with WRA, by case classification for each state and all states combined. In the 1993 to 1997 data, there were 1915 confirmed cases from all exposures in the four states, of which 236 (12.3%) were associated with cleaning products. From 1998 to 2012, there were 9667 confirmed cases of WRA from all exposures in the five states, of which 1199 (12.4%) were associated with cleaning products. There were 852 confirmed cases classified by WRA type and another 347 cases confirmed but not classified as to type of WRA. Fifty-four percent of the classifiable WRA cases were classified as new-onset asthma in comparison to 79.7% from 1993 to 1997.

Table 1 also shows the distribution of WRA cases by sex, average and range of age, race, Hispanic ethnicity, and workers' compensation filing status by state and all states combined. Most cases were women (77.8%), white non-Hispanic (62.1%), and the average age was 43 years, ranging from 16 to 74 (89.8% were 25 to 64). Approximately half (54.8%) had applied for workers' compensation. Not shown in the table, individuals classified as having RADS were more likely to apply for workers' compensation than those with work aggravated (63.8% vs 51.9%, $P = 0.02$) or occupational asthma (63.8% vs 52.7%, $P = 0.04$). Also, whites were more likely to apply than blacks (56.1% vs 42.6%, $P = 0.01$). There was no difference by sex or Hispanic ethnicity.

Table 2 shows the highest percentage, (30.7%) of cases worked in Hospitals (NAICS 622), followed by Educational Services (NAICS 611), similar to the results from 1993 to 1997.

Table 3 shows that the three most common occupations among adults with WRA associated with cleaning products were building cleaning workers (SOC 37–2010) (20.3%); registered nurses (SOC 29–1110) (14.1%); and nursing, psychiatric, and home health aides (SOC 31–1010) (5.3%), similar to the results from 1993 to 1997.

Table 4 shows the most common cleaning products reported by WRA classification type and overall. The top three exposures for all WRA classification types were cleaning materials or household general purpose cleaners that were not specified (31.2%), floor strippers or waxes (15.8%), and bleach (12.3%). Disinfectant cleaners were the next most common exposure for all WRA classification types, except for cases classified as RADS, where improper cleaning product mixtures (such as bleach plus acid, or bleach plus ammonia, which react to produce chlorine gas and chloramine vapors, respectively) were reported most frequently (14.2%).

Table 5 compares cases who worked in cleaning occupations with those exposed to cleaning products in all other occupations by WRA classification. Cases in cleaning occupations were more likely to be classified as new-onset asthma as compared with cases in non-cleaning occupations (relative risk [RR] = 1.3, 95% confidence interval [CI] = 1.2–1.5). This difference for cleaning and non-cleaning occupations for new onset asthma was seen with a known inducer (RR = 2.0, 95% CI = 1.4–2.9) but not with an unknown inducer (RR = 1.1; 95% CI = 0.8–1.4). The demographics of individuals in cleaning occupations included fewer women (66.7% vs 82.2%, $P \leq 0.0001$), more African-Americans (26.3% vs 14.8%, $P = 0.001$), and more Hispanics (20.3% vs 12.4%, $P = 0.02$) than those in non-cleaning occupations.

As shown in Table 6, a higher proportion of new-onset asthma cases in cleaning occupations reported exposure to bleach (RR = 1.6, 95% CI = 1.1 to 2.5) as well as acids, bases, or oxidizers (RR = 3.7, 95% CI = 1.6 to 8.8), compared with those in non-

TABLE 1. Work-Related Asthma Cases Associated With Cleaning Products by Case Classification Category, Demographics, and State: California, Massachusetts, Michigan, New Jersey, and New York, 1993 to 2012*

	1993–1997	1998–2012					
	CA, MA, MI, NJ	California	Massachusetts	Michigan	New Jersey	New York	CA, MA, MI, NJ, NY
Classification†	Number (%)	Number (%)	Number (%)	Number (%)	Number (%)	Number (%)	Number (%)
Total	236	603	144	285	74	93	1199
Work aggravated	48 (20.3)	182 (56.5)	41 (31.8)	100 (35.3)	24 (42.1)	45 (73.8)	392 (46.0)
New onset	188 (79.7)	140 (43.5)	88 (68.2)	183 (64.7)	33 (57.9)	16 (26.2)	460 (54.0)
Reactive airways dysfunction syndrome	42 (17.8)	43 (13.4)	22 (17.1)	67 (23.7)	8 (14.0)	1 (1.6)	141 (16.5)
Occupational asthma	146 (61.9)	97 (30.1)	66 (51.2)	116 (41.0)	25 (43.9)	15 (24.6)	319 (37.4)
Known inducer	21 (8.9)	22 (6.8)	34 (26.4)	26 (9.2)	6 (10.5)	6 (9.8)	94 (11.0)
Unknown inducer	125 (53.0)	75 (23.3)	32 (24.8)	90 (31.8)	19 (33.3)	9 (14.8)	225 (26.4)
Not classified	–¶	281	15	2	17	32	347
Demographics							
Gender							
Women	178 (75.4)	474 (78.6)	118 (81.9)	222 (77.9)	52 (70.3)	67 (72.0)	933 (77.8)
Average age (range)‡	41 (18–68)#	44 (17–71)	45 (18–69)	42 (16–73)	41 (19–65)	41 (19–74)	43 (16–74)
Race/Ethnicity§							
Non-Hispanic	193 (87.7)#	252 (75.0)	114 (89.8)	258 (98.1)	44 (84.6)	46 (75.4)	714 (85.1)
White	150 (68.2)	155 (46.1)	102 (80.3)	195 (74.1)	30 (57.7)	39 (63.9)	521 (62.1)
Black/African-American	30 (13.6)	53 (15.8)	10 (7.9)	58 (22.1)	13 (25.0)	6 (9.8)	140 (16.7)
Other	13 (5.9)	44 (13.1)	2 (1.6)	5 (1.9)	1 (1.9)	1 (1.6)	53 (6.3)
Hispanic	27 (12.3)	84 (25.0)	13 (10.2)	5 (1.9)	8 (15.4)	15 (24.6)	125 (14.9)
Applied for workers' compensation?	108 (57.8)#	166 (57.0)	63 (52.1)	110 (48.0)	22 (61.1)	32 (80.0)	393 (54.8)
Awarded/Pending	68 (63.0)	127 (76.5)	43 (68.3)	87 (79.1)	13 (59.1)	16 (50.0)	286 (72.8)

%, Percent.

*Data are available for California (CA), Massachusetts (MA), and Michigan (MI) for the period between 1993 and 2012, New Jersey (NJ) between 1993 and 2011, and New York (NY) between 2009 and 2012.

†Denominator for asthma classification percent excludes the not classified cases.

‡Age is defined as the difference between the reporting source year and year of birth. Missing date of birth on six individuals (California-3 and New Jersey-3) from 1998 to 2012.

§Race/Ethnicity was unknown for 360 individuals (California-267, Massachusetts-17, Michigan-22, New Jersey-22, and New York-32) from 1998 to 2012 and 16 individuals (California-2, Massachusetts-4, and Michigan-10) from 1993 to 1997.

?Workers' compensation information was missing for 482 individuals (California-312, Massachusetts-23, Michigan-56, New Jersey-38, and New York-53) from 1998 to 2012 and 49 individuals (California-37, Massachusetts-1, Michigan-8, and New Jersey-3) from 1993 to 1997.

¶Confirmed, but not classified cases was not an option for classification of cases during the 1993 to 1997 time period.

#Estimates are slightly different than what was published in 2003 because additional case information was received.

cleaning occupations. Among cases with work-aggravated asthma, those in cleaning occupations were also more likely to report exposure to bleach (RR = 1.7, 95% CI = 1.0 to 2.9), as well as improper cleaning product mixtures (RR = 3.4, 95% CI = 1.3 to 8.8) and disinfectants (RR = 2.0, 95% CI = 1.1 to 3.8), although absolute numbers of cases in each category were small. Floor strippers/floor waxes were less commonly reported among those in cleaning occupations with either work aggravated (RR = 0.3, 95% CI = 0.1 to 0.7) or new-onset (RR = 0.6, 95% CI = 0.4 to 1.0).

Not shown in a table, the RADS cases in cleaning occupations were more likely to report exposure to improper cleaning product mixtures when compared with RADS cases in non-cleaning occupations (22.2% to 10.8%, RR = 2.1, 95% CI = 1.1 to 4.0). Among the occupational asthma cases, a higher proportion of those in cleaning occupations reported exposure to bleach and acids, bases, or oxidizers when compared with those in non-cleaning occupations (15.1% to 8.1%, RR = 1.9, 95% CI = 1.1 to 3.2 and 6.5% to 1.2%, RR = 5.2, 95% CI = 1.6 to 16.6, respectively). All confirmed WRA cases in the Healthcare & Social Assistance industry sector reported more exposures related to floor stripper or waxes than cases reported in all other industries combined (26.7% to 7.7%, RR = 3.5, 95% CI = 2.7 to 4.5).

A case report from each state is in Appendix 2, http://links.lww.com/JOM/A673.

DISCUSSION

The 2003 publication reported 236 patients with confirmed WRA associated with cleaning products, or 12.3% of all confirmed WRA cases in the four states from 1993 through 1997.[1] This was approximately 47 cases per year. From 1998 to 2012, those same four states confirmed 1106 WRA cases associated with cleaning products, 12.4% of all cases, approximately 74 cases per year. Another 93 cases were reported from NY from 2009 to 2012. New York did not conduct WRA surveillance during 1993 to 1997. The surveillance data indicate that the current percentage of WRA cases associated with cleaning products is similar to reports in the early 1990's and that cleaning products remain an important contributor to the risk of WRA. Cleaning materials (not specified cleaning materials and household, general purpose cleaners) and bleach were two of the top three cleaning products reported in this study and in the 2003 publication. However, more cases reported floor strippers or floor waxes (15.8%) and less acids, bases, or oxidizers (2.8%) as compared with the previous report (5.3% and 7.7%, respectively). That the percentage of WRA cases associated with cleaning products has not changed indicates that continued efforts to increase knowledge of the potential hazards of cleaning products are needed, such as better presentation of information on labels and increased workplace training and education. Work aggravated asthma was

TABLE 2. Industries Where Exposure to Cleaning Products was Associated With Work-Related Asthma: California, Massachusetts, Michigan, New Jersey, and New York, 1993 to 2012*

	1993–1997†		1998–2012	
	CA, MA, MI, NJ		CA, MA, MI, NJ, NY	
Industry (North American Industry Classification System, 2002)	**Number**	**Percent‡**	**Number**	**Percent**
Healthcare and social assistance (622–624)	93	39.6	480	41.1
Hospitals (622)	66	28.1	358	30.7
Nursing and residential care facilities (623)	14	6.0	53	4.5
Ambulatory health care services (621)	13	5.5	42	3.6
Social assistance (624)	0	–	27	2.3
Educational services (611)	31	13.2	97	8.3
Administrative and support services (561)	6	2.6	67	5.7
Food services and drinking places (722)	5	2.1	51	4.4
Justice, public order, and safety activities (922)	10	4.3	50	4.3
Food and beverage stores (445)	8	3.4	40	3.4
Accommodation (721)	14	6.0	38	3.3
General merchandise stores (452)	0	–	32	2.7
Transportation equipment manufacturing (336)	6	2.6	18	1.5
Amusement, gambling, and recreation industries (713)	6	2.6	18	1.5
Executive, legislative, and other general government support (921)	3	1.3	18	1.5
Food manufacturing (311)	4	1.7	15	1.3
Transit and ground passenger transportation (485)	2	0.9	13	1.1
Professional, scientific, and technical services (541)	2	0.9	12	1.0
Insurance carriers and related activities (524)	0	–	11	0.9
All other industries	45	19.1	207	17.7
Total§	235		1167	

*Data are available for California (CA), Massachusetts (MA), and Michigan (MI) for the period between 1993 and 2012, New Jersey (NJ) between 1993 and 2011, and New York (NY) between 2009 and 2012.

†Cases identified between 1993 and 1997 are presented here with North American Industry Classification System codes instead of the 1987 Standard Industrial Classification used in the earlier publication.

‡Denominators for percentages exclude cases with missing industry information.

§The cases with missing industry information are excluded from the total; one case in California from 1993 to 1997 and 32 cases (California-16, Massachusetts-1, Michigan-4, New Jersey-3, and New York-8) from 1998 to 2012.

more common in this current update compared with the previous report (46.0% vs 20.3%) (Table 1). This change in the more recent time period likely reflects greater awareness of work-aggravated asthma by health practitioners and the increased use of hospital/emergency department and poison control center records to identify WRA by the states doing surveillance.

As in our earlier publication, we did *not* include situations involving the cleaning of medical equipment (eg, endoscopes), or cleaning in specialized industrial settings (eg, parts in a degreaser tank or paint manufacturing equipment). The focus of this study was to examine exposure to cleaning products that are frequently used for cleaning and/or disinfecting surfaces in the general work environment. This would include products used by workers in cleaning occupations that might potentially expose their fellow workers who were not cleaning in the work areas. A broader definition of cleaning would have captured more cases. For example, cases associated with skin sanitizers used by health care workers were excluded from our case definition. We note a recent article that reported that the likelihood of poor asthma control among female nurses was associated with their frequency of arm hygiene with disinfectants.[17] In addition, although situations involving disinfecting pool water[18] or cleaning animals may lead to widespread exposure, we did not include exposures in these settings.

Unlike our data, surveillance systems in other countries have reported changes in the frequency with which cleaning products are associated with WRA. In a Canadian tertiary care clinic, cleaning products have become the most common cause of WRA from 2008 to 2015 (18%) in comparison to the period from 2000 to 2007 (6%).[19] Significant increasing trends for work-related asthma from quaternary ammonium cleaning products were noted among healthcare workers in the French surveillance system, 1.4% to 8.3% from 2001 to 2009.[20] An increase in occupational asthma due to all cleaning agents was also observed in the United Kingdom surveillance system in the West Midlands from 1991 to 2011 where cleaning products were the reported cause in 5% of cases.[21] Like our data, The Health and Occupation Research (THOR) surveillance network system that covers all of the United Kingdom reported no change in the 6% of all non-asbestos respiratory disease that were attributed to cleaning agents from 1989 to 2017, despite a 6.8% annual decrease in all reported work-related asthma.[22] The periods reported in our analyses and these other surveillance systems do not completely overlap and may explain part of the differences.

During 1998 to 2012, 54.0% of WRA cases associated with cleaning products were classified as new-onset asthma, which was less than the 79.7% observed in 1993 to 1997 (Table 1). This could potentially reflect substitution or better control of substances known to cause asthma that are ingredients of cleaning products. However, the change in percentage is more likely reflective of changes in sources of surveillance in the states, which have become more dependent on administrative databases and hospital medical records that identify all types of WRA, rather than reports from individual clinicians, who are more likely to report new-onset WRA.

The demographics of WRA cases with exposure to cleaning products is similar to the previous report; most cases were women (77.8%) and white non-Hispanic (62.1%), with an average age of 43 years. The percent applying for workers' compensation has not changed substantially; 58% from 1993 to 1997 and 55% from 1998 to 2012 (Table 1). The demographics of individuals who were in cleaning occupations compared with non-cleaning occupations included fewer women, more African-Americans, and more Hispanics. The increased percentage of cases of work-related asthma in cleaning occupations who were African-American or Hispanic

TABLE 3. Occupations Where Exposure to Cleaning Products was Associated With Work-Related Asthma: California, Massachusetts, Michigan, New Jersey, and New York, 1993 to 2012*

	1993–1997†		1998–2012	
	CA, MA, MI, NJ		CA, MA, MI, NJ, NY	
Occupation (Standard Occupational Classification, 2000)	**Number**	**Percent‡**	**Number**	**Percent**
Building and grounds cleaning and maintenance occupations (37)	53	23.6	262	23.4
Building cleaning workers (37–2010)	42	18.7	227	20.3
First-line supervisors/managers, building and grounds cleaning and maintenance workers (37–1010)	11	4.9	31	2.8
All other building and grounds cleaning and maintenance occupations	0	–	4	0.4
Healthcare practitioners and technical occupations (29)	46	20.4	230	20.5
Registered nurses (29–1110)	32	14.2	158	14.1
Licensed practical and licensed vocational nurses (29–2060)	1	0.4	20	1.8
Clinical laboratory technologists and technicians (29–2010)	1	0.4	11	1.0
Miscellaneous health technologists and technicians (29–2090)	0	–	12	1.1
Emergency medical technicians and paramedics (29–2040)	1	0.4	8	0.7
Therapists (29–1120)	3	1.3	5	0.4
All other healthcare practitioners and technical occupations	8	3.6	16	1.4
Office and administrative support occupations (43)	35	15.6	144	12.9
Office clerks, general (43–9060)	4	1.8	29	2.6
Secretaries and administrative assistants (43–6010)	6	2.7	13	1.2
First-line supervisors/managers of office and administrative support workers (43–1010)	1	0.4	13	1.2
Stock clerks and order fillers (43–5080)	2	0.9	12	1.1
Receptionists and information clerks (43–4170)	1	0.4	12	1.1
Dispatchers (43–5030)	2	0.9	9	0.8
File clerks (43–4070)	1	0.4	7	0.6
Customer service representatives (43–4050)	0	–	7	0.6
Interviewers, except eligibility and loan (43–4110)	1	0.4	6	0.5
All other office and administrative support occupations	17	7.6	36	3.2
Healthcare support occupations (31)	10	4.4	88	7.9
Nursing, psychiatric, and home health aides (31–1010)	8	3.6	59	5.3
Miscellaneous healthcare support occupations (31–9090)	2	0.9	27	2.4
All other healthcare support occupations	0	–	2	0.2
Food preparation and serving related occupations (35)	13	5.8	74	6.6
Cooks (35–2010)	2	0.9	29	2.6
Fast food and counter workers (35–3020)	0	–	9	0.8
Miscellaneous food preparation and serving related workers (35–9090)	4	1.8	8	0.7
Dishwashers (35–9020)	2	0.9	7	0.6
First-line supervisors/managers, food preparation and serving workers (35–1010)	0	–	7	0.6
All other food preparation and serving related occupations	5	2.2	14	1.2
Cashiers (41–2010)	2	0.9	23	2.1
Laborers and material movers, hand (53–7060)	2	0.9	22	2.0
Miscellaneous production workers (51–9190)	6	2.7	11	1.0
Retail salespersons (41–2030)	1	0.4	13	1.2
Social workers (21–1020)	0	–	13	1.2
All other occupations	57	25.3	240	21.4
Total§	225		1120	

*Data are available for California (CA), Massachusetts (MA), and Michigan (MI) for the period between 1993 and 2012, New Jersey (NJ) between 1993 and 2011, and New York (NY) between 2009 and 2012.

†Cases identified between 1993 and 1997 are presented here with Standard Occupational Classification codes instead of the 1990 Census Occupational Codes used in the earlier publication.

‡Denominators for percentages exclude cases with missing industry information.

§The cases with missing occupation information are excluded from the total; 11 cases (California-9 and New Jersey-2) from 1993 to 1997 and 79 cases (California-42, Massachusetts-5, Michigan-13, New Jersey-6, and New York-13) from 1998 to 2012.

presumably reflects the unequal distribution of the workforce with African-Americans and Hispanics working in lower pay and more hazardous jobs.[23]

Cleaning products are commonly used across all industry sectors and confirmed cases had worked in all industry sectors (Table 2). Because of their widespread use, it should not be surprising that cases were more common in non-cleaning occupations (77.6%, Table 5) (Also see case reports from California and New York in Appendix 1, http://links.lww.com/JOM/A672). The most common industry where cases worked was in a hospital (30.7%, Table 2) and presumably reflects frequent and widespread use of surface disinfectants, some of which are known to cause sensitization and asthma (Table 7). Exposure to quaternary ammonium compound (Quats) disinfectants has been identified as a high risk among health care workers[24] and with poor asthma control in nurses,[25] but in the latter study of nurses only in relationship to cleaning medical instruments. In this later study, formaldehyde, glutaraldehyde, bleach, hydrogen peroxide, and enzymatic cleaners but not Quats and alcohol used on surfaces were associated with poor asthma control.[25]

Reviews of the use of disinfectants in health care settings have concluded that more studies are needed to develop guidelines

TABLE 4. Reported Exposures Among Work-Related Asthma Cases by Cleaning Product and Case Classification Category: California, Massachusetts, Michigan, New Jersey, and New York, 1998 to 2012*

			New-Onset Asthma (NOA)							
	Work-Aggravated Asthma		Reactive Airways Dysfunction Syndrome		Occupational Asthma		Total NOA Cases		All Confirmed Cases	
Cleaning Product Category †	***n***	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	**%**
Cleaning materials (not specified cleaning materials and household, general purpose cleaners)	156	29.1	51	24.2	166	35.0	217	31.7	513	31.2
Floor strippers/Floor waxes	108	20.1	23	10.9	66	13.9	89	13.0	259	15.8
Bleach	67	12.5	34	16.1	47	9.9	81	11.8	202	12.3
Disinfectant (not specified disinfectants, not specified disinfectant cleaners, and pine oil cleaner)	43	8.0	9	4.3	39	8.2	48	7.0	118	7.2
Carpet cleaner	25	4.7	11	5.2	14	3.0	25	3.7	76	4.6
Improper cleaning product mixtures	20	3.7	30	14.2	8	1.7	38	5.6	72	4.4
Quaternary ammonia compounds	18	3.4	6	2.8	32	6.8	38	5.6	66	4.0
Ammonia	17	3.2	7	3.3	11	2.3	18	2.6	53	3.2
Acids, bases, or oxidizers	15	2.8	8	3.8	14	3.0	22	3.2	46	2.8
Chemicals, not specified	9	1.7	3	1.4	7	1.5	10	1.5	26	1.6
Alcohols (not specified alcohols, ethanol, and isopropyl alcohol)	7	1.3	0	–	7	1.5	7	1.0	20	1.2
Glycol ethers (not specified ethylene glycol ethers, ethylene glycol monomethyl ether, and 2-butoxyethanol)	4	0.7	4	1.9	4	0.8	8	1.2	18	1.1
Soaps, detergents, and laundry soaps	6	1.1	1	0.5	2	0.4	3	0.4	17	1.0
Hydrocarbons (not specified aromatic hydrocarbons, toluene, and xylene) and solvents, not specified	4	0.7	1	0.5	9	1.9	10	1.5	16	1.0
Cleaners (abrasive, acid, caustic, and citric)	6	1.1	2	0.9	3	0.6	5	0.7	15	0.9
Oven cleaner	3	0.6	3	1.4	2	0.4	5	0.7	14	0.9
Inorganic halogens (chlorine, chlorine dioxide, chlorous acid, and sodium chlorite)	5	0.9	2	0.9	4	0.8	6	0.9	14	0.9
Graffiti remover	2	0.4	1	0.5	4	0.8	5	0.7	12	0.7
Ethanolamines	3	0.6	3	1.4	4	0.8	7	1.0	11	0.7
Toilet bowl cleaner	0	–	1	0.5	3	0.6	4	0.6	11	0.7
All other cleaning products‡	18	3.4	11	5.2	28	5.9	38	5.6	63	3.8
Total§	536		211		474		684		1642	

*Data are available for California (CA), Massachusetts (MA), and Michigan (MI) for the period between 1998 and 2012, New Jersey (NJ) between 1998 and 2011, and New York (NY) between 2009 and 2012.

†See Appendix for the Association of Occupational and Environmental Clinics (AOEC) Exposure Codes associated with each cleaning product category.

‡All other cleaning products' represents cleaning products (see Appendix) with counts less than 10.

§Individuals can report exposures up to three cleaning products. For work-aggravated asthma cases, 265 had exposure to 1, 110 to 2, and 17 to 3 cleaning products. For reactive airways dysfunction syndrome cases, 87 had exposure to 1, 38 to 2, and 16 to 3 cleaning products. For occupational asthma cases, 196 had exposure to 1, 92 to 2, and 31 to 3 cleaning products. For new-onset asthma cases, 283 had exposure to 1, 130 to 2, and 47 to 3 cleaning products. For all confirmed work-related asthma cases, 828 had exposure to 1, 299 to 2, and 72 to 3 cleaning products.

TABLE 5. Work-Related Asthma Cases Associated With Cleaning Products by Case Classification Category: A Comparison Between Cleaning Occupations and All Other Occupations, 1993 to 1997 and 1998 to 2012*

	1993–1997			1998–2012		
	Cleaning Occupations †	All Other Occupations		Cleaning Occupations	All Other Occupations	
Classification	**Number (%)**	**Number (%)**	**RR (95% CI)**	**Number (%)**	**Number (%)**	**RR (95% CI)**
Total‡	53	172		184	636	
Work aggravated	7 (13.2)	38 (22.1)	0.6 (0.3–1.3)	61 (33.2)	315 (49.5)	0.7 (0.5–0.8)
New onset	46 (86.8)	134 (77.9)	1.1 (1.0–1.3)	123 (66.8)	321 (50.5)	1.3 (1.2–1.5)
Reactive airways dysfunction syndrome	11 (20.8)	28 (16.3)	1.3 (0.7–2.4)	38 (20.7)	97 (15.3)	1.4 (1.0–1.9)
Occupational asthma	35 (66.0)	106 (61.6)	1.1 (0.9–1.3)	85 (46.2)	224 (35.2)	1.3 (1.1–1.6)
Known inducer	4 (7.5)	25 (14.5)	0.5 (0.2–1.4)	34 (18.5)	59 (9.3)	2.0 (1.4–2.9)
Unknown inducer	31 (58.5)	81 (47.1)	1.2 (0.9–1.6)	51 (27.7)	165 (25.9)	1.1 (0.8–1.4)

%, percent; CI, confidence interval; RR, relative risk.

*Data are available for California (CA), Massachusetts (MA), and Michigan (MI) for the period between 1993 and 2012, New Jersey (NJ) between 1993 and 2011, and New York (NY) between 2009 and 2012.

†Cleaning occupations are those with the following 2000 Standard Occupational Classification codes: 37–1010 (First-Line Supervisors/Managers, Building and Grounds Cleaning and Maintenance Workers), 37–1011 (First-Line Supervisors/Managers of Housekeeping and Janitorial Workers), 37–2010 (Building Cleaning Workers), 37–2011 (Janitors and Cleaners, Except Maids and Housekeeping Cleaners), 37–2012 (Maids and Housekeeping Cleaners), and 37–2019 (Building Cleaning Workers, All Other).

‡Cases with missing classification for asthma type or occupation are not included. For 1993 to 1997, all cases were classified by asthma type and 11 cases had missing occupation information (California-9 and New Jersey-2). For 1998 to 2012, 347 cases were not classified by asthma type (California-281, Massachusetts-15, Michigan-2, New Jersey-17, and New York-32) and 79 cases had missing occupation information (California-42, Massachusetts-5, Michigan-13, New Jersey-6, and New York-13).

TABLE 6. Reported Exposures Among Work-Related Asthma Cases by Cleaning Product and Case Classification Category: A Comparison Between Cleaning Occupations* and All Other Occupations, 1998 to 2012†

	Work-Aggravated Asthma				New-Onset Asthma				All Confirmed Cases			
	Cleaning Occupations		All Other Occupations		Cleaning Occupations		All Other Occupations		Cleaning Occupations		All Other Occupations	
Cleaning Product Category‡	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
Cleaning materials (not specified cleaning materials and household, general purpose cleaners)	32	36.8	121	28.4	55	27.2	150	32.6	126	32.9	356	30.8
Floor strippers/Floor waxes	6	6.9	99	23.2	18	8.9	70	15.2	29	7.6	215	18.6
Bleach	17	19.5	48	11.3	33	16.3	46	10.0	60	15.7	128	11.1
Disinfectant (not specified disinfectants, not specified disinfectant cleaners, and pine oil cleaner)	12	13.8	29	6.8	13	6.4	34	7.4	29	7.6	83	7.2
Carpet cleaner	0	–	25	5.9	3	1.5	21	4.6	4	1.0	66	5.7
Improper cleaning product mixtures	7	8.0	10	2.3	16	7.9	21	4.6	29	7.6	37	3.2
Quaternary ammonia compounds	1	1.1	15	3.5	14	6.9	24	5.2	18	4.7	45	3.9
Ammonia	5	5.7	9	2.1	6	3.0	12	2.6	12	3.1	35	3.0
Acids, bases, or oxidizers	2	2.3	11	2.6	13	6.4	8	1.7	19	5.0	22	1.9
Chemicals, not specified	1	1.1	7	1.6	3	1.5	7	1.5	8	2.1	17	1.5
Alcohols (not specified alcohols, ethanol, and isopropyl alcohol)	0	–	7	1.6	2	1.0	5	1.1	3	0.8	16	1.4
Glycol ethers (not specified ethylene glycol ethers, ethylene glycol monomethyl ether, and 2-butoxyethanol)	0	–	4	0.9	3	1.5	5	1.1	3	0.8	14	1.2
Soaps, detergents, and laundry soaps	0	–	6	1.4	0	–	3	0.7	2	0.5	14	1.2
Hydrocarbons (not specified aromatic hydrocarbons, toluene, and xylene) and solvents, not specified	1	1.1	3	0.7	2	1.0	8	1.7	4	1.0	12	1.0
Cleaners (abrasive, acid, caustic, and citric)	0	–	6	1.4	3	1.5	2	0.4	4	1.0	10	0.9
Oven cleaner	0	–	3	0.7	1	0.5	4	0.9	1	0.3	11	1.0
Inorganic halogens (chlorine, chlorine dioxide, chlorous acid, and sodium chlorite)	1	1.1	4	0.9	2	1.0	4	0.9	4	1.0	9	0.8
Graffiti remover	0	–	1	0.2	1	0.5	4	0.9	4	1.0	7	0.6
Ethanolamines	1	1.1	1	0.2	0	–	7	1.5	1	0.3	9	0.8
Toilet bowl cleaner	0	–	0	–	3	1.5	1	0.2	7	1.8	4	0.3
All other cleaning products§	1	1.1	17	4.0	11	5.4	24	5.2	16	4.2	44	3.8
Total?	87		426		202		460		383		1154	

*Cleaning occupations are those with the following 2000 Standard Occupational Classification codes: 37–1010 (first-line supervisors/managers, building and grounds cleaning and maintenance workers), 37–1011 (first-line supervisors/managers of housekeeping and janitorial workers), 37–2010 (building cleaning workers), 37–2011 (janitors and cleaners, except maids and housekeeping cleaners), 37–2012 (maids and housekeeping cleaners), and 37–2019 (building cleaning workers, all other).

†Data are available for California, Massachusetts, and Michigan for the period between 1998 and 2012, New Jersey between 1998 and 2011, and New York between 2009 and 2012.

‡See Appendix for the Association of Occupational and Environmental Clinics (AOEC) Exposure Codes associated with each cleaning product category.

§"All other cleaning products" represents cleaning products (see Appendix) with counts less than 10.

?Totals represent number of exposures for cases in cleaning and non-cleaning occupations by case classification category. Percentages are based on all exposures within each case classification category and occupation category.

on both the frequency and surfaces on which they should be used.[12] For example, do non-patient contact areas such as hallway floors need to be disinfected? Other work has questioned the efficacy of the widespread use of disinfectants in non-health care settings such as homes, schools, and childcare centers. Brochures and guidelines for the use of bleach and other disinfectants, cleaning in general, and cleaning in schools and childcare centers have been developed.[26–32] A cross-sectional survey of custodians found that custodians had more dermal, upper, and lower respiratory symptoms with increasing use of traditional cleaning products, some of which contained disinfectants, than with increasing use of environmentally preferable cleaning products, defined as cleaning products in the EcoLogo or Green Seal databases.[33] The criteria used by EcoLogo and Green Seal to define green cleaning agents at the time of the cross-sectional survey of custodians prohibited asthma causing agents.

TABLE 7. Disinfectants Reported to Cause Sensitization and Asthma (16)

Chlorine based
Bleach (sodium hypochlorite)
Chloramine T
Chlorhexidine
Hexachlorophene
Quaternary ammonium chloride compounds
Aldehydes
Formaldehyde
Glutaraldehyde
peroxide
Mixture of hydrogen peroxide and peracetic acid

There are three main limitations to our surveillance data. First, in accordance with standard medical practice in the United States, although all the confirmed cases are physician diagnosed cases of WRA, less than 10% of the cases in Michigan and New Jersey where copies of all breathing tests performed are requested, had pulmonary function tests performed in relation to work and/or exposure.[34] This lack of confirmatory pulmonary function testing presumably may lead to the inclusion of cases with irritative symptoms from work but who do not have WRA. Second, the identification of the suspected causal agents is based on self-reported history. Since specific antigen bronchoprovocation testing is generally not available to health care practitioners in the United States, this testing was not performed.

Neither patients nor their providers may be able to identify the true causal agent as many products may have multiple ingredients and no specific antigen challenge testing is available. Moreover, workers who are bystanders may only know that cleaning had taken place in their area, but not know what types of products had been used. In addition, workers may report indoor air or mold as the causal agent but not know that cleaning products have been used and that these cleaning products are the actual cause of their respiratory symptoms. Finally, the state-based surveillance systems only received a fraction of the WRA cases within the five states. However, there is no reason to suspect that there is increased reporting for cleaning products versus better-known causes of WRA such as the isocyanates. One could hypothesize the opposite, that work-related asthma cases among minority and low-wage workers who were more likely to work in jobs using cleaning products were less likely to have access to medical care and therefore less likely to be reported.

The percentage of confirmed cases of WRA associated with cleaning products among states doing surveillance for WRA in the United States has not changed since being reported by these states in the mid 1990's. Evaluation of different intervention approaches to reduce the occurrence of WRA from cleaning products would be useful to identify the most effective preventive measures. Such evaluation efforts are needed to understand how to best reduce the unnecessary use of disinfectants in both health care and non-health care settings, identify safer products and methods (including non-chemical cleaning methods), and implement safer work practices. These preventive actions are needed to reduce health effects to both those using cleaning products and individuals in the workplace exposed as bystanders. Potentially additional benefits would accrue to the public, patients and children who are in these same buildings.

REFERENCES

1. Rosenman KD, Reilly MJ, Schill DP, et al. Cleaning products and work-related asthma. *J Occup Environ Med*. 2003;45:556–563.
2. Folletti I, Zock J-P, Moscato G, Siracusa A. Asthma and rhinitis in cleaning workers: a systematic review of epidemiological studies. *J Asthma*. 2014;51:18–28.
3. Siracusa A, De Blay F, Folletti I, et al. Asthma and exposure to cleaning products - a European Academy of Allergy and Clinical Immunology task force consensus statement. *Allergy*. 2013;68:1532–1545.
4. Moore VC, Sherwood Burge P, Robertson AS, Walters GI. What causes occupational asthma in cleaners? *Thorax*. 2017;72:581–583.
5. Weinmann T, Gerlich J, Heinrich S, et al. Association of household cleaning agents and disinfectants with asthma in young German adults. *Occup Environ Med*. 2017;74:684–690.
6. Svanes O, Bertelsen RJ, Lygre SHL, et al. Cleaning at home and at work in relation to lung function decline and airway obstruction. *Am J Respir Crit Care Med*. 2018;197:1157–1163.
7. Lee HS, Chan CC, Tan KT, Cheong TH, Chee CB, Wang YT. Burnisher's asthma–a case due to ammonia from silverware polishing. *Singapore Med J*. 1993;34:565–566.
8. Purohit A, Kopferschmitt-Kubler MC, Moreau C, Popin E, Blaumeiser M, Pauli G. Quaternary ammonium compounds and occupational asthma. *Int Arch Occup Health*. 2000;73:423–427.
9. Nagy L, Orosz M. Occupational asthma due to hexachlorophene. *Thorax*. 1984;39:630–631.
10. Beaudouin E, Kanny G, Morisset M, et al. Immediate hypersensitivity to chlorhexidine: literature review. *Eur Ann Allergy Clin Immunol*. 2004;36:123–126.
11. Kujala VM, Reijula KE, Ruotsalainen EM, Heikkinen K. Occupational asthma due to chloramine-T solution. *Respir Med*. 1995;89:693–695.
12. Cristofari-Marquand E, Kacel M, Milhe F, Magnan A, Lehucher-Michel MP. Asthma caused by peracetic acid-hydrogen peroxide mixture. *J Occup Health*. 2007;49:155–158.
13. Zock JP, Plana E, Jarvis D, et al. The use of household cleaning sprays and adult asthma: an international longitudinal study. *Am J Respir Crit Care Med*. 2007;176:735–741.
14. Quinn M, Henneberger PK, Braun B, et al. Cleaning and disinfecting environmental surfaces in health care: towards an integrated framework for infection and occupational illness prevention. *Am J Infect Control*. 2015;43:424–434.
15. Jajosky RA, Harrison R, Reinisch F, et al. Surveillance of work-related asthma in selected U.S. states using surveillance guidelines for state health departments–California, Massachusetts, Michigan, and New Jersey, 1993–1995. Morbidity and Mortality Weekly Report. *CDC Surveillance Summaries*. 1999;48:1–20.
16. Rosenman KD, Beckett WS. Web based listing of agents associated with new onset work-related asthma. *Respir Med*. 2015;109:625–631.
17. Dumas O, Varraso R, Boggs KM, et al. Association of hand and arm disinfection with asthma control in US nurses. *Occup Environ Med*. 2018;75:378–381.
18. Thickett KM, McCoach JS, Gerber JM, Sadhra S, Burge PS. Occupational asthma caused by chloramines in indoor swimming-pool air. *Eur Respir J*. 2002;19:827–832.
19. Gotzev S, Lipszyc JC, Connor D, Tarlo SM. Trends in occupations and work sectors among patients with work-related asthma at a Canadian tertiary care clinic. *Chest*. 2016;150:811–818.
20. Paris C, Ngatchou-Wandji J, Luc A, et al. Work-related asthma in France: recent trends for the period 2001–2009. *Occup Environ Med*. 2012;69:391–397.
21. Walters GI, Kirkham A, McGrath EE, Moore VC, Robertson AS, Burge PS. Twenty years of SHIELD: decreasing incidence of occupational asthma in the West Midlands, UK? *Occup Environ Med*. 2015;72:304–310.
22. Carder M, Seed MJ, Money A, Agius RM, van Tongeren M. Occupational and work-related respiratory disease attributed to cleaning products. *Occup Environ Med*. 2019;76:530–536.
23. Stanbury M, Rosenman KD. Occupational health disparities: a state public health-based approach. *Am J Ind Med*. 2014;57:596–604.
24. Gonzalez M, Jégu J, Kopferschmitt MC, et al. Asthma among workers in healthcare settings: role of disinfection with quaternary ammonium compounds. *Clin Exp Allergy*. 2014;44:393–406.
25. Dumas O, Wiley AS, Quinot C, et al. Occupational exposure to disinfectants and asthma control in US nurses. *Eur Respir J*. 2017;50:1700237.
26. California Department of Public Health, Occupational Health Branch, Work-Related Asthma Prevention Program. Healthy Cleaning & Asthma-Safer Schools: A How-To Guide [California Department of Public Health web site]; 2014. Available at: https://tinyurl.com/CLASSguidelines. Accessed August 26, 2019.
27. Healthy Schools Network. Disinfecting and Sanitizing in Child Care Centers: Model Recommendations from San Francisco Asthma Task Force [HealthySchools.org web site]; 2012. Available at: http://healthyschools.org/data/files/San_Francisco_disinfecting_and_asthma__factsheet_2012.pdf. Accessed August 26, 2019.
28. Michigan State University, College of Human Medicine, Department of Medicine, Occupational & Environmental Medicine Division. Cleaning and Sanitizing With Bleach at the Workplace: What You Need to Know! - Guidelines for Employees [Michigan State University web site]; 2017. Available at: http://www.oem.msu.edu/images/resources/BleachBrochureJuly2017.pdf. Accessed August 26, 2019.
29. Commonwealth of Massachusetts, Department of Public Health, Occupational Health Surveillance Program. Clean Safe – Follow the EEC Cleaning Guidelines [Massachusetts Department of Public Health web site]. Available at: http://files.hria.org/files/AS934.pdf. Accessed August 26, 2019.
30. Rose L, Westinghouse C. Cleaning for Healthier Schools – Infection Control Handbook. [California Department of Public Health web site]; 2010. Available at: https://www.cdph.ca.gov/Programs/CCDPHP/DEODC/OHB/WRAPP/CDPH%20Document%20Library/CleanSchoolsHandbook.pdf. Accessed August 26, 2019.
31. Mount Sinai, Selikoff Centers for Occupational Health, Bellevue/NYU Occupational & Environmental Medicine Clinic. Quaternary Ammonium Compounds in Cleaning Products: Health & Safety Information for Cleaners and Supervisors. [Mount Sinai web site]; 2015. Available at: https://www.mountsinai.org/files/MSHealth/Assets/HS/Patient-Care/Service-Areas/Occupational-Medicine/QACsInfoforWorkers_18.pdf. Accessed August 26, 2019.
32. Mount Sinai, Selikoff Centers for Occupational Health, Bellevue/NYU Occupational & Environmental Medicine Clinic. Quaternary Ammonium Compounds in Cleaning Products: Health & Safety Information for Health Professionals. [Mount Sinai web site]; 2015. Available at: https://www.mountsinai.org/files/MSHealth/Assets/HS/Patient-Care/Service-Areas/Occupational-Medicine/QACsInfoforPhysicians_18.pdf. Accessed August 26, 2019.
33. Garza JL, Cavallari JM, Wakai S, et al. Traditional and environmentally preferable cleaning product exposure and health symptoms in custodians. *Am J Ind Med*. 2015;58:988–995.
34. Rosenman KD. Asthma and work: how do you diagnose the association? *Chest*. 1991;100:1481–1482.

