Cleaning Products and Work-Related Asthma

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To describe the characteristics of individuals with work-related asthma associated with exposure to cleaning products, data from the California-, Massachusetts-, Michigan-, and New Jersey state-based surveillance systems of work-related asthma were used to identify cases of asthma associated with exposure to cleaning products at work. From 1993 to 1997, 236 (12%) of the 1915 confirmed cases of work-related asthma identified by the four states were associated with exposure to cleaning products. Eighty percent of the reports were of new-onset asthma and 20% were work-aggravated asthma. Among the new-onset cases, 22% were consistent with reactive airways dysfunction syndrome. Individuals identified were generally women (75%), white non-Hispanic (68%), and 45 years or older (64%). Their most likely exposure had been in medical settings (39%), schools (13%), or hotels (6%), and they were most likely to work as janitor/cleaners (22%), nurse/nurses' aides (20%), or clerical staff (13%). However, cases were reported with exposure to cleaning products across a wide range of job titles. Cleaning products contain a diverse group of chemicals that are used in a wide range of industries and occupations as well as in the home. Their potential to cause or aggravate asthma has recently been recognized. Further work to characterize the specific agents and the circumstances of their use associated with asthma is needed. Additional research to investigate the frequency of adverse respiratory effects among regular users, such as housekeeping staff, is also needed. In the interim, we recommend attention to adequate ventilation, improved warning labels and Material Safety Data Sheets, and workplace training and education. (J Occup Environ Med. *2003;45:556–563*)

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Cleaning products are widely used both at work and in the home. Workplace exposure to cleaning products is ubiquitous and occurs both in industrial and nonindustrial settings. Exposure may occur during prescribed use as well as after spills or inappropriate mixing. Tens of thousands of workers' primary job responsibilities involve the use of cleaning products, and even more workers may also be exposed when cleaning products are used in their work areas.

There are a limited number of reports of new-onset work-related asthma occurring after a documented exposure to cleaning products,[1–4] or exposure to common components of cleaning products.[5,6] Exacerbation of pre-existing asthma from such exposures has also been reported.[7,8]

Some cleaning products have been marketed to reduce exposure to asthma triggers such as dust mites and molds. For example, the Soap and Detergent Association, a nonprofit trade association whose members produce 90% of the cleaning products sold in the United States, initiated a campaign in 1999 called "Clean and Healthy. . . Strategies for Today's Homes: Allergies and Asthma." However, two home care products advertised to reduce dust mites in carpets were recently recalled after they were reported to trigger asthma attacks.[9] The potential of cleaning products to cause or aggravate asthma has not been widely recognized.

In this article, we have reviewed the reports of work-related asthma associated with cleaning products received by California, Massachusetts, Michigan, and New Jersey, the four states that conduct work-related

asthma surveillance as part of the Sentinel Event Notification System for Occupational Risks (SENSOR).[10,11]

Methods

Details of how SENSOR work-related asthma (WRA) cases are identified and the criteria for case confirmation and classification have previously been published.[11] All WRA reports in California, more than 99% in Massachusetts, and more than 80% in Michigan and New Jersey were received as reports from physicians. Such reports were actively solicited in Massachusetts, Michigan, and New Jersey. The California system was based on administrative data linked to physician reimbursement for medical services. Massachusetts, Michigan, and New Jersey identified additional cases by reviewing all hospital discharge records with the 9th International Classification of Diseases (ICD) code 506.0–506.9 (respiratory conditions due to chemical fumes and vapors) or with the ICD-9 code 493–493.3 (asthma) where workers' compensation was the primary payer. After cases were reported, standardized follow-up questionnaires were administered by telephone in all four states to obtain additional information about workplace exposures associated with asthma symptoms. For each case, up to three exposure agents were recorded as the possible cause of the asthma. Michigan and New Jersey also regularly reviewed medical records for pulmonary function tests to assess whether testing was performed in relation to work and, if so, the results of that testing.

Based on the questionnaire results from the interviews, and in Michigan and New Jersey review of the medical records for pulmonary function tests results, cases were confirmed as being work-related and were classified as either being work-aggravated asthma, or new-onset work-related asthma.[11] New-onset WRA cases were further classified into asthma without a latency period between exposure and disease (reactive airways dysfunction syndrome, or RADS) or asthma with a latency period.[12] RADS is a type of asthma that occurs after exposure to high concentrations of an irritating substance. Chlorine and chloramines, both irritating substances, can be produced when certain cleaning products that should not be mixed are mixed. Asthma cases with a latency period were classified as having exposure to a known asthma inducer or exposure to an unknown asthma inducer. Each state used the Association of Occupational and Environmental Clinics exposure system to code agents to which individuals were exposed. Agents documented in the medical literature[13] to induce asthma have been identified in the coding system with the letter "A." The exposure codes are available on the internet at http://www.aoec.org/aoeccode.htm.[14]

Data on confirmed cases of work-related asthma were forwarded to the National Institute for Occupational Safety and Health for inclusion in a multistate database of WRA cases.

To identify cases with exposure to cleaning products, all cases of WRA reported during the years 1993–1997 were reviewed. All confirmed cases in which a cleaning product was identified as the suspected agent were counted. A cleaning product was defined as any material used for cleaning and/or disinfecting surfaces in the general work environment. In some cases, these cleaning products contained pesticides or antiseptics. Exposures may have occurred after spills or improper mixing. We included both water-based and solvent-based products. Because we were interested in examining cleaning products that are potentially widely used both at work and by the general public, 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). Although more widely performed, situations involving the disinfecting of pool water, cleaning food or cleaning animals were not included.

We calculated the rate of asthma in janitors and cleaners on a subset of the data from California. These data were calculated using the annual number of asthma cases among janitors and cleaners from 1993–2001 identified by the SENSOR program in California as the numerator and 1990 census data for the number of individuals who work as janitors and cleaners in California as the denominator.

Results

A total of 1915 confirmed cases of WRA were identified by the four states from 1993–1997. A cleaning product was one (or more) of the three suspected agents identified for 236 (12%) of the 1915 confirmed cases. Table 1 shows the number and percentage of cases associated with cleaning products by asthma classification and state. Most of the asthma was new onset (80%) and in most cases the potential causal agent has not been previously reported to cause occupational asthma. Table 2 shows the gender, date of birth, racial distribution, and workers' compensation filing status by state reported. Most cases were women (75%), white (68%), in their mid-30s or older. Half applied for workers' compensation (58%). Table 3 shows the industries worked by state. The largest percentage (67%) had worked in the service industry. The common occupations in those industries are shown in Table 4. Janitors, nurses, nurse's aides, and clerical workers were the three largest occupations reported. The most common cleaning products reported are shown in Table 5.

The rate of WRA in California among janitors and cleaners is 4.3/100,000 workers compared with 2.3/100,000 workers for all other occupations combined. The occupations with the highest rates were firefighters at 28.6/100,000 and correctional officers at 27.7/100,000. Four exam-

TABLE 1
Number and Percentage of Cases of Work-Related Asthma That Were Associated with Cleaning Products by Case Classification Category and State: California, Massachusetts, Michigan, and New Jersey, 1993–1997

	California		Massachusetts		Michigan		New Jersey		Total	
Classification	#	%	#	%	#	%	#	%	#	%
Total	92		49		79		16		236	
Work aggravated	26	(28)	2	(4)	17	(22)	3	(19)	48	(20)
New onset	66	(72)	47	(96)	62	(79)	13	(81)	188	(80)
Reactive airways Dysfunction syndrome	5	(5)	6	(12)	26	(33)	5	(31)	42	(18)
Occupational asthma	61	(66)	41	(84)	36	(46)	8	(50)	146	(62)
Known inducer	7	(8)	10	(20)	3	(4)	1	(6)	21	(9)
Unknown inducer	54	(59)	31	(63)	33	(42)	7	(44)	125	(53)

TABLE 2
Number and Percentage of Cases of Work-Related Asthma Associated with Cleaning Products by Gender, Date of Birth, Race/Ethnicity, Workers' Compensation Filing Status, and State: California, Massachusetts, Michigan, and New Jersey, 1993–1997

	California		Massachusetts		Michigan		New Jersey		Total	
	#	%	#	%	#	%	#	%	#	%
Gender										
Women	71	(77)	38	(78)	58	(73)	11	(69)	178	(75)
Year of birth										
1925–1947	32	(35)	13	(27)	23	(29)	4	(25)	72	(31)
1948–1957	30	(33)	20	(41)	24	(30)	6	(38)	80	(34)
1958–1967	18	(20)	11	(22)	17	(22)	3	(19)	49	(21)
1968–1976	12	(13)	5	(10)	15	(19)	3	(19)	35	(15)
Race/ethnicity[a]										
White (non-hispanic)	54	(60)	35	(76)	56	(72)	11	(69)	156	(68)
African-American	7	(8)	4	(9)	18	(23)	3	(19)	32	(14)
Hispanic	20	(22)	3	(7)	3	(4)	2	(13)	28	(12)
Other	9	(10)	4	(9)	1	(1)	0		14	(6)
Applied for workers' comp[b]	33	(60)	32	(67)	34	(48)	9	(69)	108	(58)
Total	92		49		79		16		236	

[a] Missing Race/Ethnicity on six individuals (California-two, Massachusetts-three, Michigan-one).
[b] Missing information on workers' compensation on 49 individuals (California-37, Massachusetts-one, Michigan-eight, New Jersey-three).

ples of typical cases reported are summarized below.

Case Report #1 (California)

A 55-year-old nonsmoking man had worked for a large urban school district as a custodian since 1978. In December of 1995 he was assigned to clean a building within a high school that contained large amounts of graffiti. He used several different graffiti-removal products, sometimes up to 4 hours per day, 5 days per week. Sometimes he had to remove graffiti from small spaces such as bathroom stalls and stairways, where there was little ventilation. He had never been provided with any information about the chemicals in the graffiti-removal products, their health effects, or any instructions on using the products safely. He developed symptoms of wheezing, cough, and chest tightness. These symptoms were significantly worse when he was assigned to do graffiti removal. He left work on the advice of his doctor but remained symptomatic despite the use of steroid and metaproterenol inhalers. Material safety data sheets for two of the graffiti removal products he used showed the following ingredients: one contained dimethyl glutarate, dimethyl adipate, γ-butyrolactone, ethylene glycol n-butyl ether, dimethyl succinate, and propylene glycol butyl ether; and the other contained d-limonene, alkyl polyglycoside, and propylene carbonate. This case met the surveillance case criteria because of the temporal relationship of his symptoms to exposure and a doctor's diagnosis of asthma. No pulmonary function testing was available.

Case Report #2 (Massachusetts)

A 59-year-old Haitian woman sought medical care for episodes of exertional dyspnea and occasional chest pain that started 3 months prior

TABLE 3
Primary Industries Where Exposure to Cleaning Products was Associated with Work-Related Asthma: California, Massachusetts, Michigan, and New Jersey, 1993–1997

Industry (SIC)[a]	Number	Percent
Agriculture (01–09)	6	(3)
Construction (17)	2	(1)
Manufacturing (20–39)	23	(10)
Food and kindred products (20)	5	
Chemicals and allied products (28)	5	
Other (30, 31, 33, 35, 36, 37)	13	
Transportation, communication, and utilities (41–49)	6	(3)
Whole sale (50, 51)	5	(2)
Retail trade (52–59)	16	(7)
Food store (54)	9	
Eating and drinking places (58)	5	
Miscellaneous retail (59)	2	
Finance, insurance and real estate (60–67)	3	(1)
Services (70–89)	158	(67)
Hotel, rooming houses, camps, and other lodging (70)	14	
Business (73)	7	
Health (80)	92	
Education (82)	30	
Other (72, 76, 79, 81, 83, 84, 86, 89)	15	
Government (91–97)	17	(7)
Justice, public, and safety (92)	10	
Other (91, 93, 94, 97)	7	
Total	236	

[a] SIC, standard industrial classification.

TABLE 4
Common Occupations Where Exposure to Cleaning Products was Associated with Work-Related Asthma: California, Massachusetts, Michigan, and New Jersey, 1993–1997

Occupation	Number	Percent
Janitors, cleaners, and housekeepers	52	(22)
Nurses and nurses' aides	47	(20)
Clerical	31	(13)
Operators, fabricators, and laborers	18	(8)
Managers and supervisors	16	(7)
Food preparation	13	(6)
Precision production, craft and repair occupations	12	(5)
Other medical occupations	12	(5)
Teachers	8	(3)
Police and guards	5	(2)
Bartenders, waiters, and Waitresses	4	(2)
Other	18	(8)
Total	236	

to her medical evaluation. Episodes occurred about two to three times per week while walking, climbing stairs, and/or carrying something. On further questioning, she recalled chest tightness and shortness of breath for the previous 5 years. She further described that she experienced symptoms during the workday, when she went home from work, and that they became worse throughout the workweek. Her symptoms improved on vacation. She had worked as a housekeeper for 26 years in the same hospital.

She had a history of upper gastrointestinal discomfort, which was diagnosed as gastritis and treated with omeprazole. After a negative stress test and normal electrocardiogram, she had pulmonary function testing. On spirometry her FEV_1 was 81% of predicted and her FEV_1/FVC was 85%. Her FEV_1 improved 0.32 L (17% improvement) with a bronchodilator.

The hospital contracted with a cleaning company that obtained all of its products from one supplier. The case associated her asthma symptoms with three products from this supplier. One of the products had been discontinued 2 years before her interview, after 4 years of use, and contained an amine. The two other products remained in use. One product contained two quaternary ammonium compounds, *n*-alkyl dimethyl benzyl ammonium chloride and didecyl dimethyl ammonium chloride. The other product contained 2-phenyl phenol and *o*-benzyl-*p*-chlorophenol. The fact that the quaternary ammonium compounds may cause respiratory sensitization was not included on the material safety data sheets.

Although the patient reported several symptomatic coworkers, the hospital management said they were unaware of any employee with health problems associated with the use of the cleaning products. The patient continued to work, despite her physician's recommendation that she change jobs. This case met the surveillance criteria because of the temporal relationship of her symptoms to work, evidence of hyperreactivity, doctor's diagnosis of asthma and exposure to a known occupational allergen.

Case Report #3 (Michigan)

A woman in her 30s worked as a cake decorator and at the deli counter at a supermarket. She developed wheezing, cough, chest tightness, and shortness of breath 2 hours after she mopped up some drain cleaner that had been used to unclog a sink drain but had then spilled out onto the floor. She was hospitalized for 3 days and was given steroids and

TABLE 5
Number of Cases of Work-Related Asthma Associated with Different Types of Cleaning Products: California, Massachusetts, Michigan, and New Jersey, 1993–1997

Agent	Number of Cases
Cleaning materials, household cleaners (not specified)	107
Bleach	43
Acids, bases, oxidizers	23
Disinfectants (not specified)	20
Carpet cleaner	17
Floor Stripper/waxes	16
Ammonia	14
Mixing bleach and acid or ammonia	11
Glutaraldehyde	8
Graffiti remover	8
Soaps	5
Ethanol	4
Quaternary ammonia	3
Formaldehyde	3
Ethylene glycol monobutylether	3
Ethanolamines	3
Oven cleaner	2
Sulfonates	2
Caustic	2
Phenols	2
Limonene	2
Glass cleaner	2
Copier cleaner	1
Iodophors	1
Total	300[a]

[a] 182 individuals had exposure to 1, 44 to 2, and 10 to 3 cleaning products.

albuterol. Seven months after the exposure, her FEV_1 was 51% of predicted. No further pulmonary function tests were available. One and a half years later, she still had breathing problems and was still using asthma medicine. She never had asthma before this incident although she had a history of food allergies. She had never smoked cigarettes. She had a son with asthma. This case met the surveillance case criteria because of the onset of her respiratory symptom after exposure to an irritant at work, her ongoing respiratory problems, and a physician diagnosis of asthma.

Case Report #4 (New Jersey)

A 55-year-old white Hispanic female who never smoked cigarettes had a 2-year history of wheezing, cough, shortness of breath, and chest tightness. She had been a housekeeper in a hospital for 8 years, with duties that included general cleaning of offices and floors. Her symptoms had begun after 6 years on the job and were worse when at work, especially when she had used cleaning products in small rooms. She particularly had noted symptoms when she used a floor cleaner that contained quaternary ammonium salts, ethyl alcohol, and sodium hydroxide. Her symptoms had been occasionally triggered while she had used cleaning products around her house. She had no history of asthma, bronchitis, or allergic rhinitis prior to onset of symptoms at work. She had no family history of allergies. She had been hospitalized on one occasion for 2 weeks at the age of 54 for dyspnea and a chest infection. She had quit her job after 8 years because of her illness, and after 6 weeks away from work her symptoms had markedly decreased. Her medications included albuterol and pirbuterol. This case met the surveillance case criteria because of the temporal relationship of her symptoms to work, a doctor's diagnosis of asthma and exposure to a known occupational allergen. No pulmonary function testing was available.

Discussion

Cleaning products are frequently reported as exposures (12%) for the WRA cases in the SENSOR Surveillance System. The individuals reported were generally women (75%), white non-Hispanic (68%), and 35 years or older (64%; Table 2). Individuals, such as those described in our case reports, had most likely been exposed to cleaning products while working in a medical setting (39%), a school (13%), or a hotel (6%; Table 3). Cleaning was not the usual primary task of many individuals exposed to cleaning products who were reported with WRA. Although janitors and cleaners were the most common occupations reported and had a higher rate of WRA than other occupations combined based on the California data, only 22% of the WRA cases were employed as janitors and cleaners. Nurses and nurses' aides (20%) and clerical staff (13%) were the next most common occupations (Table 4).

Most of the cases reported were new-onset asthma (80%), although aggravation of pre-existing asthma was not uncommon (20%). Generally, for the new-onset asthma, no known inducer of sensitization was identified by interview of the reported case or, in Michigan and New Jersey, through review of medical records. In fact, for 36% of the substances identified as being associated with WRA, the usual information obtained was no more specific than "cleaning compound" or "carpet cleaner" (Table 5). Of the cleaning products identified, the most common were irritants such as acids, ammonia, or bleach; and disinfectants such as formaldehyde, glutaraldehyde, and quaternary ammonia compounds (Table 5).

Inappropriate mixing of incompatible cleaning products was the re-

ported cause in 4% of the reported cases of WRA but the reported association with bleach and other irritants was for the most part related to the sole use of that irritant and not to the mixing of cleaning products. Approximately 18% of the cases were classified as RADS. Mixing acid and bleach generates chlorine, and mixing ammonia and bleach generates chloramine. At high enough concentrations both chlorine and chloramines may cause RADS. Employee training and education for safe handling of cleaning products and review of the adequacy of warning messages on labels of cleaning products are actions that would potentially prevent inappropriate mixing.

We did not systematically collect information on the actual situation of use (ie, confined space in an unventilated bathroom), or form of product (ie, liquid versus spray), or whether the products were properly diluted. Such information would be of use to determine whether metered mixing and dispensing systems and/or training and education would be useful in preventing asthma in the non-RADS cases.

Being a cleaner has recently been recognized as an occupation at increased risk of asthma in studies from Europe and South Africa.[15,16] A follow-up study in Spain of a subset of the large European study found that this increased risk was limited to private home cleaners.[17] In a Finnish study, as in our state registries, the risk of asthma in cleaners was found across many industries including hospitals, schools, and hotels.[18] However, the greatest risk of asthma among cleaners in the Finnish study was found in food manufacturing and basic metal manufacturing.[18] Both the Spanish and Finnish study used administrative and clerical workers as the reference group and, accordingly, may underestimate the risk of cleaning products since administrative/clerical workers were also commonly reported in our work-related asthma surveillance systems (Table 4).

Other reports are consistent with cleaning products being associated with asthma morbidity and mortality. A proportionate mortality analysis of asthma deaths using the National Center for Health Statistics multiple cause of death data in the United States from 1987–1996 showed significant increased risk for hotel clerks 2.00 (95% CI = 1.03–3.49), housekeepers and butlers 1.44 (95% CI = 1.07–1.90), and private household cleaners and servants 1.33 (95% CI = 1.22–1.45).[19] Other surveillance systems have associated cleaning products with WRA but have not compiled their data to obtain estimates of the relative importance of cleaning products. A recent unpublished summary from the Surveillance of Work-Related and Occupational Respiratory Disease system in England reported 157 estimated cases from cleaning products of respiratory disorders (73% asthma, 20% inhalation accident, 3% hypersensitivity pneumonitis, and 2% rhinitis) since the inception of the project in 1989.[20]

Review of the medical literature reveals a number of reports of documented work-related asthma after exposure to specific cleaning products. These reports include cleaning products containing disinfectants such as chloramine or glutaraldehyde, which are known sensitizers,[3] a carpet cleaner containing a fungicide,[1] multiple reports of asthma that developed after a single acute cleaning agent exposure (RADS),[4] aggravation of pre-existing asthma after carpet cleaning,[8] and aggravation of asthma after exposure to a mixture of bleach and acid with development of adult respiratory distress syndrome.[7] Sensitization to an ingredient in a cleaning product has been best documented for benzyl ammonium chloride.[2,21,22]

Aliphatic polyamines are commonly found in cleaning products. Members of this chemical group that have been associated with WRA are ethylene diamine, diethylene triamine, and triethylene tetramine.[5] Similarly, the ethanolamines, mono and triethanolamine, also found in some cleaning products, have been associated with work-related asthma.[6] Only one of the asthma reports on ethanolamine involved its use in a cleaning compound, a detergent to remove floor wax.[6]

Cleaning products are used in a multitude of locations and in significant quantities. Although the top three industries (see Table 3) accounted for more than 50% of all the WRA cases in our registries, the remaining industries included manufacturing, construction, agriculture, offices, government, and a range of service industries. In addition to being used in most industries, the quantities used are substantial. A study funded by the EPA observed that the average janitor used approximately 28 gallons, or 234 pounds, of chemicals per year, of which 58 pounds were chemicals deemed hazardous.[23] The term "hazardous" used in the study included corrosive, flammable, "give off toxic fumes" and poisonous, but did not specifically include sensitizers. These ingredients were considered hazardous if they were listed on the cleaning product material safety data sheets as hazardous. Environmental Protection Agency–recommended methods to protect the environment and prevent workplace injuries by reducing the amount of dirt that enters the workplace and by selecting safer products. Reducing the need to clean reduces the potential of exposure to cleaning products. Massachusetts is encouraging state agencies to use environmentally preferable products, by certifying selected products and contractors.

The fact that more than one third of the cases of WRA in the presented data could not identify the specific product or ingredient that was associated with their symptoms indicates that more attention must be paid to the cleaning products themselves and protocols for their use. Improving the presentation of information on labels, as well as workplace training and education as mandated by the

Occupational Safety and Health Act's Hazard Communication Standard, should help to increase knowledge about the potential hazards of cleaning products.

The hazards of using cleaning products are not limited to the workplace. Cleaning products have been reported to be responsible for 24% of hospitalizations from respiratory conditions due to chemical fumes and vapors from nonworkplace exposures.[24] The presence of these products in the home may obscure the diagnosis of WRA because there may be no temporal association with work if exposure occurs both at work and at home.

Asthma is one potential outcome of exposure to cleaning products. Irritant reactions and symptoms associated with poor indoor air quality have also been reported with their use.[25,26] Other adverse health outcomes may include chemical injuries (including eye injuries and chemical burns) and poisoning and other acute overexposures.[23] Cleaning products are a common source of nonfatal work-related inhalation injuries requiring emergency room treatment.[27] In 2000, cleaning products were the third most frequent substance involved in adult exposures in the American Association of Poison Control Centers Toxic Exposure Surveillance System (66,384; 9.5%).[28] They had been the second highest substance (64,691; 9.0%) in 1999.[29]

There are three limitations of the SENSOR database. First, although the cases received are physician-diagnosed cases of WRA, only 5% of the cases have documentation of pulmonary function changes in relation to work and/or exposure.[30] The state SENSOR data reflects the practice of medical care in the United States, where work-related asthma is typically diagnosed by history. Although history is a sensitive diagnostic tool, it has been shown to have a low specificity.[31] The study results of Malo et al. indicate that up to 37% of the confirmed cases in the SENSOR database may not truly be work-related asthma despite a physician diagnosis.[31]

Second, identification of the causal agent is also based on history. Assuming the patient has WRA, many times there are multiple exposures and since no specific antigen bronchoprovocation testing is performed, the patient may not identify the true causal agent. The limitations noted above are less likely to apply to cases classified as RADS, where there is an acute exposure with an acute onset of disease. However, even with an acute exposure there may be multiple exposures and pinpointing the exact substance may not be possible.

Finally, the SENSOR surveillance systems only receive a minority of the WRA cases within their states. In Michigan, only 1.3% of physicians report to the surveillance system and the results of capture–recapture analysis provide estimates that the surveillance system missed from 53% up to 87% of cases occurring in the state.[32] We would assume that the percentage of cases reported in Massachusetts and New Jersey are similar because their reporting systems are similar to Michigan. California's system is based on an administrative database that is part of a fee reimbursement system so one would expect a higher percentage of cases that occur in California to be reported. This may also explain why the percentage of work-aggravated asthma cases is greater in California than the other states (Table I).[11]

Despite these limitations, the SENSOR surveillance system has proven useful in identifying new etiologic agents of work-related asthma, directing public health intervention, and evaluating overall magnitude and trends in work-related asthma.[11,30,32]

The definition of cleaning products used in the SENSOR surveillance system is broad and goes beyond the basic definition of water-based and surfactant-based products used to clean surfaces. The broad definition that was used in this paper also included solvent-based cleaners. However, less than 5% of cases reported were identified to have used solvent-based cleaners. The risk of using solvent-based cleaners such as graffiti removers presumably differs from traditional cleaners because of the increased volatility of the solvent-based cleaners. However, there is no epidemiologic data to evaluate the presumed difference in potential risk. Workers with cleaning responsibilities potentially have exposure to both types of products.

Current premarket testing of cleaning products and their ingredients includes assessment of their irritant effect on skin and mucosal surface and more limited testing of their potential to cause contact dermatitis. A review of the 1250 different chemicals used in cleaning products in Denmark found that 49 (4%) were known causes of contact dermatitis.[33] There is no testing of cleaning products or their ingredients for their ability to cause IgE-mediated reactions and/or asthma.

Further work is needed to investigate the potential for cleaning products and their ingredients to cause asthma. Efforts are needed in the laboratory on animal models to determine the toxicological potential for cleaning products to cause sensitization. Better follow-up of WRA cases presumed to be caused by cleaning products is also needed. Further clarifying the circumstances when the cleaning products were associated with an adverse effect (ie, confined space such as an unventilated bathroom), whether the product had been properly diluted, or the form of the product (ie, liquid versus aerosol versus spray) would assist in developing preventive strategies. Additional clinical follow-up of individual cases might include specific bronchoprovocation testing to document the responsible etiologic component of the cleaning product.

Finally, to investigate the frequency of adverse effects, epidemiologic studies of exposed cohorts, such as the housekeeping staff in

hospitals or hotels that repeatedly use cleaning products, are needed.

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