



Update on asthma and cleaning agents

Ilenia Folletti^a, Andrea Siracusa^b, and Giulia Paolucci^a

Purpose of review

Asthma due to cleaning products has been known for 20 years, and the interest in this topic is still large because of the number of cleaning workers with respiratory problems. In this review, we sought to highlight the most recent findings on the relationship between exposure to cleaning products and asthma and to summarize the specific literature published between 2013 and 2016.

Recent findings

Women are confirmed as most of workers exposed to cleaning products and have a higher frequency than men of work-related respiratory symptoms and diseases. Many cases of asthma due to cleaning products occur in healthcare occupations. The increased risk of asthma has been shown to be related to the number of years in the job and to early life disadvantage. Recent evidence suggests that predisposition to adult-onset asthma may be related to interaction between genes and occupational exposure to low-molecular weight agents/irritants. There is some evidence that an irritant mechanism is more common, although several case reports showed an immunologic mechanism (e.g. disinfectants, amine compounds, aldehydes and fragrances).

Summary

The review updated recent findings on epidemiology, cleaning agents and their mechanism, and prevention of asthma due to cleaning agents. This article provides new information on the level of exposure, which is still high in professional cleaners and even more in domestic cleaners, and on the frequency of asthma in professional and domestic cleaners. An irritant mechanism is more common, although an immunological mechanism is possible, especially in healthcare workers exposed to disinfectants.

Keywords

asthma, cleaning agents, epidemiology, occupation, risk factors, work-related

INTRODUCTION

Cleaning workers constitute a high percentage of the working population in developed countries and a number of individuals involved in professional and home cleaning are exposed to cleaning products. A systematic review of epidemiological studies, published in 2014, showed an association between exposure to cleaning products and asthma in 79% of cross-sectional, longitudinal and case-control studies [1^{*}]. Work-related asthma (WRA) comprises occupational asthma defined as a type of asthma caused by the workplace and work-exacerbated asthma (WEA), which refers to asthma triggered by various work-related factors in workers with preexisting asthma [2]. Cleaners are at risk for new-onset occupational asthma, WEA and irritant-induced asthma, due to exposure to sensitizers and irritants contained in cleaning products [3]. The fifth Jack Pepys Workshop on Asthma in the Workplace focused on similarities and differences between WRA and non-WRA and the exposure to cleaning

agents was regarded as a risk factor for both [4]. In occupational cleaners of Northern Europe, the increased risk of asthma was related to the length in years in the job and to early life disadvantage [5^{*}]. Exposure to cleaning agents often occurs in healthcare workers as recently reported by Gotzev *et al.* [6] and Mazurek and Weissman [7]. The European Academy of Allergy and Clinical Immunology (EAACI) Position Paper, published in 2013, highlighted that

^aDepartment of Medicine, Section of Occupational Medicine, Respiratory Diseases, Occupational and Environmental Toxicology and
^bDepartment of Clinical and Experimental Medicine, University of Perugia, Perugia, Italy

Correspondence to Dr Ilenia Folletti, Department of Medicine, Section of Occupational Medicine, Respiratory Diseases, Occupational and Environmental Toxicology, University of Perugia, Perugia, 06132, Italy. Tel: +39 0744 205 554; fax: +39 0744 205 762; e-mail: ilenia.folletti@unipg.it

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KEY POINTS

- More women than men are employed as professional and home cleaners and seem to be more predisposed to asthma due to cleaning products.
- Many cases of cleaning-related asthma occur in healthcare workers.
- Risk factors are level and length of exposure, female sex and early life disadvantage, whereas atopy and smoking seem less important.
- Poor psychosocial working conditions seem to contribute to the high prevalence of asthma in cleaners.
- Predisposition to adult-onset asthma may be related to interaction between genes and occupational exposure to low-molecular weight agents/irritants, such as cleaning products.
- There is evidence that an irritant mechanism is more common, although several case reports showed an immunologic mechanism, particularly in healthcare workers exposed to disinfectants.
- Asthma related to cleaning agents is a preventable disease, but it is necessary to better identify risk factors in longitudinal studies.
- Phenotyping asthma associated with cleaning products exposure and identifying biomarkers is a crucial point to manage the disease and to formulate prevention strategies.

in cleaning workers, the increased risk of WRA, WEA and rhinitis is mainly associated with exposure to cleaning sprays, bleach, ammonia, disinfectants and mixing products [8].

In this article, we reviewed the most recently published articles on the relationship between cleaning work and asthma and summarized the specific literature published in 2013–2016.

EPIDEMIOLOGY

Most of workers exposed to cleaning products are women and work part-time, whereas about 30% of cleaning workers are migrant workers [9]. Women more often tended to have a higher risk for asthma than men and 17.3% of new-onset asthma cases in men and 5.1% in women may be attributed to occupational exposure [10].

The risk of WRA in individuals exposed to cleaning products does not seem dependent on atopic status, supporting the view that a mechanism different from 'classic' allergy is involved. This mechanism could be irritant (deterministic) or sensitization (stochastic) as observed for occupational asthma caused by some low molecular weight agent

(LMW) agents [11]. There is little support that the risk of asthma is increased in smokers exposed to cleaning products [12]. Poor psychosocial working conditions may partly explain the high prevalence of asthma due to cleaning products and a stress-induced inflammatory immune response may contribute to the onset of WRA in cleaners [13].

Exposure assessment studies in healthcare workers were conducted from 2009 to 2011 at five hospitals of the United States [14]; cleaning and disinfecting tasks were performed with a high frequency at least once per shift in many occupations; for example medical equipment preparers, housekeepers, floor strippers/waxers and endoscopy technicians spent on average 2–3 h/shift performing cleaning/disinfecting tasks. A Canadian clinical survey of WRA cases in the period 2008–2015 found that in the last half of the period surveyed, cleaning products were relatively more often an attributed cause than in the first half [6]. In the Australian Workplace Exposure Study-Asthma among 2437 interviewed women, 20% were exposed to industrial cleaning and sterilizing agents [15].

Norwegian female cleaners had an increased risk of job change, used as a marker of respiratory work disability [odds ratio (OR) 5.7, 95% confidence interval (CI) 2.3–14.0] [16]. Moreover, the large use of cleaning sprays at home may have significant implications for public health; for example Zock *et al.* [11] estimated that one in seven adult asthma cases may be related to the use of household cleaning sprays. Data from Poland and Spain showed that professional cleaning women are at an increased risk of occupational asthma, WRA and WEA due to cleaning products [17,18].

A high number of cases of WRA occurred in healthcare occupations such as operating room nursing from occupational exposure to disinfectant/cleaning agents [19,20].

In the review of occupational asthma notification from the Midland Thoracic Society's Surveillance Scheme of Occupational Asthma database, Walters *et al.* [19] reported that occupational asthma related to cleaning products was an emerging cause in UK healthcare workers after 2001. A recent study [5] hypothesized that early life disadvantage (maternal smoking in childhood, severe respiratory infection <5 years of age, being born in winter and/or maternal age at delivery >35 years) may increase the risk of asthma and respiratory symptoms due to exposure to cleaning agents later in life; this risk increased with years in occupational cleaning. Exposure to cleaning agents (both at home and in the workplace) plays an important role in adult-onset asthma, and an association was observed between uncontrolled adult-onset asthma and exposure to cleaning agents (OR

2.0, 95% CI 1.2–3.3) with stronger associations for long-term exposures [21,22].

AGENTS

Available evidence indicates that cleaning materials can both exacerbate asthma (WEA) and induce the development of new-onset asthma (occupational asthma) [23,24]. There is little information on the specific agents involved in the various phenotypes of asthma related to cleaning exposure. Most epidemiological studies [24,25] have linked asthma with exposure to irritant cleaning materials, mainly bleach, ammonia and cleaning/degreasing sprays. Rava *et al.* [26[■]] showed that ever exposure to low-molecular weight agents/irritants, such as cleaning products and disinfectants, was associated with current adult-onset asthma and identified novel genes potentially involved in adult asthma associated with occupational exposure.

Questionnaire, skin prick test and bronchial responsiveness challenge were assessed in 607 women [27]. Frequent use of bleach for home cleaning was associated with current asthma (OR 1.7, 95% CI 1.0–3.0), nonallergic asthma (OR 3.3, 95% CI 1.5–7.1) and nonallergic adult-onset asthma (OR 4.9, 95% CI 2.0–11.6). The conclusion of this study was that the domestic use of bleach for cleaning is associated with nonallergic asthma in women.

The highest risk of reported asthma was associated with tasks involving dilution of disinfection products by manual mixing, suggesting possible exposure to repeated peaks of concentrated irritant/sensitizing products such as quaternary ammonium compounds [28[■]]. In a retrospective case series analysis, Vandenplas *et al.* [29] suggested that quaternary ammonium compounds are the principal cause of sensitizer-induced occupational asthma among cleaners.

Moreover, two interesting reviews published in 2010 suggested that occupational asthma in cleaning workers may be due to specific sensitization to disinfectants such as quaternary ammonium compounds (e.g. benzalkonium chloride and lauryl dimethyl benzyl ammonium chloride), chloramine T, glutaraldehyde, fragrances and ethanolamines [3,30].

Furthermore, occupational activities of cleaning workers are associated with exposure to airborne biological agents, such as *Penicillium* and *Aspergillus* species, which may be responsible for occupational asthma [31[■]]. In a case series of 20 patients, occupational asthma was attributed not only to cleaning chemicals but also to moulds, such as *Aspergillus fumigatus* [32].

Few studies evaluated quantitative assessments of respiratory exposures to airborne irritants and

sensitizers. Recently, Swiss authors evaluated workers exposed to cleaning products airborne concentrations of monoethanolamine, glycol ethers, benzyl alcohol and formaldehyde during different cleaning tasks [33[■]]. Professional cleaners were found to be exposed to multiple airborne irritants at low concentrations, thus the level of these substances should be assessed in the cleaning industry, especially in specialized cleaning tasks such as intensive floor cleaning [33[■]].

Weekly household use of cleaning sprays should have an effect on asthma, but no association was observed among elderly women who received household help [34].

MECHANISMS

The mechanisms involved in asthma associated with cleaning products and disinfectants are not clear. Both allergic and irritant mechanisms are involved, but the latter is the most relevant [8,35,36]. Inflammatory Th₂ response is activated after airway epithelium damage as a consequence of repeated irritant exposure [37]. Individuals who use hypochlorite bleach to clean their homes were at risk of respiratory symptoms but were less likely to be atopic [38]. Women exposed to bleach in domestic cleaning were at risk of adult-onset asthma and nonallergic asthma (OR 3.3, 95% CI 1.5–7.1) and the frequency of women with 'high neutrophils' cell counts profile increased from 21 to 30 and 46%, respectively, in those using bleach less than 1 day per week, 1–3 days per week and 4–7 days per week [27].

Some cleaning agents or disinfectants, such as quaternary ammonium compounds, have both irritant and sensitizer effects [28[■]]. Benzalkonium chloride induces specific immunoglobulin E and eosinophilic inflammatory response and can cause bronchoconstriction [39–41]. The retrospective case series analysis published by Vandenplas *et al.* [29] showed an increase in bronchial hyperreactivity and sputum eosinophils after specific inhalation challenge (SIC) with cleaning agents and disinfectants. The cleaning sensitizer products responsible were quaternary ammonium compounds, glutaraldehyde and ethanolamines. In a Polish study [17[■]], cleaners experienced cleaning-related respiratory symptoms, allergic and irritant effects. Those results support the hypothesis of a sensitizing mechanism involved in some cases of asthma related to cleaning agent exposure.

The study of Corradi *et al.* [42] provided evidence on whether professional cleaning was associated with biomarkers of lung damage in noninvasively collected biological fluids [exhaled air and exhaled breath condensate (EBC)]. They identified the potential biomarkers of exposure to alkaline products (increased ammonium-EBC and pH-EBC levels) and

potential biomarkers of oxidative stress (increased H₂O₂-EBC levels correlated with 4-hydroxynonenal-EBC levels) in those exposed to cleaning agents. Then, a case-control study conducted by Vizcaya *et al.* [23] in cleaners with asthma symptoms did not show differences in levels of Cys-leukotrienes and 8-isoprostane in EBC. Recently, a pattern of genes involved in the mechanism of allergic and nonallergic asthma was identified and therefore the hypothesis of a role of genes in the development of occupational asthma was proposed [43].

Rava *et al.* [26^{***}] analyzed genes involved in response to oxidative stress related to occupational exposure to LMW agents/irritants in three large population studies (Epidemiological study on the Genetics and Environment of Asthma, bronchial hyperresponsiveness and atopy, Swiss Cohort Study on Air Pollution and Lung and Heart Diseases in Adults and European Community Respiratory Health Survey). They identified novel genes involved in adult asthma related to occupational exposure activating the nuclear factor kappa-light-chain-enhancer of activated B cells pathway. Recent epidemiological studies strengthen the evidence of an effect of chronic exposure to irritants in WRA, and the underlying mechanism may be related to oxidative stress, neurogenic inflammation and dual irritant and adjuvant effects [44].

The oxidative stress response was recently hypothesized in relation to asthma in cleaners working in unsafe conditions. Radon *et al.* [13^{***}] found that the higher prevalence of asthma in cleaners should be explained also by poor psychosocial working conditions and a mechanism of inflammatory response stress induced could be considered. Moreover, disadvantage in early life seems to have a role in the airway vulnerability of workers exposed to cleaning agents later in life [5^{***}].

DIAGNOSIS

Asthma and WRA associated with cleaning agents exposure are well documented by numerous epidemiological studies [1^{***},8,44] and recently, review articles showed strength of this evidence. Cleaning agents contain a wide range of ingredients that are irritants as chlorine or ammonia and potential sensitizers as quaternary ammonium compounds and perfumes [1^{***},8,44]. In some cases, there occurred acute exposure to high level of agents and workers experienced reactive airway dysfunction syndrome [45]. Most of the studies assessed self-reported asthma symptoms by questionnaire. Two studies [46,47] showed that peak expiratory flow variability is not sensitive and not related to respiratory symptoms associated with cleaning agents exposure.

The diagnosis of asthma should be assessed as suggested by international guidelines (GINA) and the diagnosis of WRA as indicated in the documents published by American and European societies of respiratory and allergic diseases (American Thoracic Society, EAACI and European Respiratory Society). SICs are the reference test for specific etiological diagnosis of WRA [2]. Vandenplas *et al.* [29] performed a retrospective case series analysis of patients affected by WRA who underwent SICs with cleaning products. Thirty-nine percent had a positive SIC-confirmed asthma related to cleaning agents. Bleach was one of the cleaning agents more frequently associated with asthma symptoms. Sastre *et al.* [48] performed SIC in 13 patients with asthma-like symptoms related to bleach exposure and asthmatic reaction, two late and one dual, occurred in three individuals. Because of scarce knowledge of mechanisms of asthma due to cleaning agents and lack of available biomarkers diagnosis in clinical setting is difficult. Therefore, to better manage the patients experienced asthma symptoms associated with cleaning products, suggestions published by the EAACI should be taken into account [35].

PREVENTION

Review articles on occupational asthma summarize primary, secondary (early detection) and tertiary (appropriate treatment) prevention strategies aimed at reduction of the onset and severity of work-related respiratory diseases [37,49]. Primary prevention, such as avoidance of workplace exposure, should be the most effective strategy to reduce the onset of sensitization, occupational asthma and occupational rhinitis [37,49,50]. Surprisingly, prevention of work-related respiratory diseases in cleaners has seldom been studied in spite of the large knowledge on the dimension of the problem and identification of specific products and job tasks responsible for work-related asthma and rhinitis [1^{***},8].

In the years 2013–2014, three reviews on epidemiology and prevention of work-related asthma and rhinitis due to cleaning products have emphasized that cleaning sprays, bleach, ammonia and disinfectants (e.g. quaternary ammonium compounds and glutaraldehyde) have been identified as the most common agents of occupational asthma and occupational rhinitis in cleaning workers [1^{***},8,51^{***}]. Among disinfectants, exposure to quaternary ammonium compound was more commonly reported than exposure to glutaraldehyde [51^{***}].

Inhalation accidents in cleaners, such as mixing bleach and ammonia in a small, poorly ventilated area, were associated with asthma symptoms, reactive airway dysfunction syndrome, irritant-induced

occupational asthma and WEA (8Syracusa). Moreover, specific job tasks, such as kitchen cleaning and furniture polishing, cleaning windows, washing dishes, mopping/waxing the floor, spot-cleaning carpets and cleaning tiles and grout, have been identified as causes or exacerbation of asthma [52–55].

Ideally, good cleaning products that are safer for the respiratory system should be available. Unfortunately, the conclusions of research on cleaners have seldom been heeded by manufactures, vendors and commercial cleaning companies. However, few examples of effective prevention have been reported, such as replacing some cleaning agents with less hazardous materials; for example avoidance of glutaraldehyde exposure has been partially achieved by using the less volatile ortho-phthalaldehyde [56] or using cleaning products that are wiped, not sprayed and of low volatility which has been associated with less asthma [11]. Moreover, the burden of work-related respiratory symptoms and asthma in cleaners can be reduced by avoiding or reducing exposure to quaternary ammonium compounds [51*].

Recently, Garza *et al.* [57*] in a cross-sectional study performed in 329 custodians analyzed the association between respiratory symptoms and exposure to traditional and 'environmentally preferable' cleaning products. The authors observed a significant increase in upper and lower respiratory symptoms associated with high exposure to traditional cleaning products compared with high exposure to environmentally preferable cleaning products. However, it was observed that environmentally preferable cleaning products are not totally safe if inhaled.

In conclusion, work-related asthma and rhinitis in cleaning workers are largely preventable diseases and it is necessary to identify specific risk factors to develop effective prevention strategies.

CONCLUSION

Over the past 20 years, the relationship between exposure to cleaning products and asthma has been repeatedly documented. Despite that, it seems that professional and domestic exposure to harmful cleaning products has continued with little improvement. There are examples of hospital and school cleaning in which hazardous products, such as glutaraldehyde and bleach, were exchanged for less hazardous materials, such as ortho-phthalaldehyde, cleaning products that are wiped, not sprayed, low volatility and 'environmentally preferable' cleaning products. Interestingly enough, predisposition to adult-onset asthma may be related to interaction between genes and adult asthma due to occupational

exposure to low-molecular weight agents/irritants. Studying genes may help in reducing the impact of cleaning products on respiratory health.

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Conflicts of interest

There are no conflicts of interest.

REFERENCES AND RECOMMENDED READING

Papers of particular interest, published within the annual period of review, have been highlighted as:

- of special interest
- of outstanding interest

1. Folletti I, Zock JP, Moscato G, Syracuse A. Asthma and rhinitis in cleaning workers: a systematic review of epidemiological studies. *J Asthma* 2014; 51:18–28.

This systematic review shows that four out of five epidemiological studies in cleaning workers show an association between work-related exposure and asthma.

2. Moscato G, Pala G, Barnig C, *et al.* EAAI consensus statement for investigation of work-related asthma in nonspecialized centres. *Eur Acad Allergy Clin Immunol Allergy* 2012; 67:491–501.
3. Zock JP, Vizcaya D, Le Moual N. Update on asthma and cleaners. *Curr Opin Allergy Clin Immunol* 2010; 10:114–120.
4. Malo JL, Tarlo SM, Sastre J, *et al.* An official American Thoracic Society Workshop Report: presentation and discussion of the fifth Jack Pepys Workshop on Asthma in the Workplace. Comparison between asthma in the workplace and nonwork-related asthma. *Ann Am Thorac Soc* 2015; 12:S99–S110.
5. Svanes O, Skorge TD, Johannessen A, *et al.* Respiratory health in cleaners in Northern Europe: is susceptibility established in early life? *PLoS One* 2015; 10:e0131959.

This article brings new findings on the relationship between early life disadvantage and the increased risk of asthma in cleaners.

6. 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.
7. Mazurek JM, Weissman DN. Occupational respiratory allergic diseases in healthcare workers. *Curr Allergy Asthma Rep* 2016; 16:77.
8. Syracuse 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.
9. Brun E editor. The occupational safety and health of cleaning workers EU-OSHA. Luxembourg: Office for Official Publications of the European Communities: European Agency for Safety and Health at Work; 2009.
10. Torén K, Ekerljung L, Kim JL, *et al.* Adult-onset asthma in west Sweden—incidence, sex differences and impact of occupational exposures. *Respir Med* 2011; 105:1622–1628.
11. Zock JP, Plana E, Jarvis D, *et al.* The use of household cleaning spray and adult asthma. An international longitudinal study. *Am J Respir Crit Care Med* 2007; 176:735–741.
12. Syracuse A, Marabini A, Folletti I, Moscato G. Smoking and occupational asthma. *Clin Exp Allergy* 2006; 36:577–584.
13. Radon K, Llanqui U, Arce A, *et al.* Job strain, bullying and violence at work and asthma in Peruvian cleaners—a cross-sectional analysis. *J Asthma* 2016; 53:1018–1025.

This original article showed that poor psychosocial working conditions seem to contribute to the high prevalence of asthma in cleaners.

14. Saito R, Virji MA, Henneberger PK, *et al.* Characterization of cleaning and disinfecting tasks and product use among hospital occupations. *Am J Ind Med* 2015; 58:101–111.
15. Fritschi L, Crewe J, Darcey E, *et al.* The estimated prevalence of exposure to asthmagens in the Australian workforce, 2014. *BMC Pulm Med* 2016; 16:48.
16. Fell AK, Abrahamsen R, Henneberger PK, *et al.* Breath-taking jobs: a case-control study of respiratory work disability by occupation in Norway. *Occup Environ Med* 2016; 73:600–606.

17. Lipinska-Ojrzanowska AA, Wiszniewska M, Walusiak-Skorupa JM. Work-related asthma among professional cleaning women. *Arch Environ Occup Health* 2016; 19:1–8. [Epub ahead of print]

This Polish study showed that professional cleaning women are at an increased risk of occupational and WEA due to cleaning products.

18. Vizcaya D, Mirabelli MC, Gimeno D, *et al.* Cleaning products and short-term respiratory effects among female cleaners with asthma. *Occup Environ Med* 2015; 72:757–763.
19. Walters GI, Moore VC, McGrath EE, *et al.* Agents and trends in healthcare workers' occupational asthma. *Occup Med (Lond)* 2013; 63:513–516.
20. Le Moual N, Varraso R, Zock JP, *et al.* Are operating room nurses at higher risk of severe persistent asthma? The Nurses' Health Study. *J Occup Environ Med* 2013; 55:973–977.
21. Le Moual N, Varraso R, Siroux V, *et al.* Domestic use of cleaning sprays and asthma activity in females. *Eur Respir J* 2012; 40:1381–1389.
22. Le Moual N, Jacquemin B, Varraso R, *et al.* Environment and asthma in adults. *Presse Med* 2013; 42 (9 Pt 2):e317–e333.
23. Vizcaya D, Mirabelli MC, Orriols R, *et al.* Functional and biological characteristics of asthma in cleaning workers. *Respir Med* 2013; 107:673–683.
24. Arif AA, Delclos GL. Association between cleaning-related chemicals and work-related asthma and asthma symptoms among healthcare professionals. *Occup Environ Med* 2012; 69:35–40.
25. Vizcaya D, Mirabelli MC, Antó JM, *et al.* A workforce-based study of occupational exposures, asthma symptoms in cleaning workers. *Occup Environ Med* 2011; 68:914–919.
26. Rava M, Ahmed I, Kogevinas M, *et al.* Genes interacting with occupational exposures to low molecular weight agents and irritants on adult-onset asthma in three European studies. *Environ Health Perspect* 2016; DOI: 10.1289/EHP376 [Epub ahead of print]

This original study provides new data on the link between some genes and adult asthma due to occupational exposure to low-molecular weight agents/irritants. These results may explain, at least partially, the predisposition toward asthma in workers exposed to cleaning products.

27. Matulonga B, Rava M, Siroux V, *et al.* Women using bleach for home cleaning are at increased risk of nonallergic asthma. *Respir Med* 2016; 117:264–271.
28. 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.

The authors of this study showed the role of disinfectants in healthcare workers with work-related asthma and highlighted the difficulties in differentiating between irritant and sensitizing activity for each cleaning agent.

29. Vandenplas O, D'Alpaos V, Evrard G, *et al.* Asthma related to cleaning agents: a clinical insight. *BMJ Open* 2013; 3:e003568.
30. Quirce S, Barranco P. Cleaning agents and asthma. *J Investig Allergol Clin Immunol* 2010; 20:542–550.
31. Golófit-Szymczak M, Górny RL, Ławniczek-Walczak A, *et al.* Bacterial and fungal aerosols in the work environment of cleaners. *Med Pr* 2015; 66:779–791.
- This study brings new findings on exposure to airborne biological agents in cleaners.
32. Mäkelä R, Kauppi P, Suuronen K, *et al.* Occupational asthma in professional cleaning work: a clinical study. *Occup Med (Lond)* 2011; 61:121–126.
33. Melchior Gerster F, Brenna Hopf N, Pierre Wild P, Vernez D. Airborne exposures to monoethanolamine, glycol ethers, and benzyl alcohol during professional cleaning: a pilot study. *Ann Occup Hyg* 2014; 58:846–859.
- In this original Swiss study, professional cleaners were found to be exposed to multiple airborne irritants at low concentrations, suggesting that the level of these substances may be harmful, especially in specialized cleaning tasks such as intensive floor cleaning.
34. Bédard A, Varraso R, Sanchez M, *et al.* Cleaning sprays, household help and asthma among elderly women. *Respir Med* 2014; 108:171–180.
35. Vandenplas O, Wiszniewska M, Raulf M, *et al.* EAACI position paper: irritant-induced asthma. *Allergy* 2014; 69:1141–1153.
36. De Matteis S, Cullinan P. Occupational asthma in cleaners: a challenging black box. *Occup Environ Med* 2015; 72:755–756.

37. Tarlo SM, Lemiere C. Occupational asthma. *N Engl J Med* 2014; 370:640–649.
38. Zock JP, Plana E, Antó JM, *et al.* Domestic use of hypochlorite bleach, atopic sensitization, and respiratory symptoms in adults. *J Allergy Clin Immunol* 2009; 124:731–738.
39. Gerberick GF, Cruse LW, Ryan CA, *et al.* Use of a B cell marker (B220) to discriminate between allergens and irritants in the local lymph node assay. *Toxicol Sci* 2002; 68:420–428.
40. Sadakane K, Ichinose T. Effect of the hand antiseptic agents benzalkonium chloride, povidone-iodine, ethanol, and chlorhexidine gluconate on atopic dermatitis in NC/Nga mice. *Int J Med Sci* 2015; 12:116–125.
41. Miszkiel K, Beasley R, Holgate S. The influence of ipratropium bromide and sodium cromoglycate on benzalkonium chloride-induced bronchoconstriction in asthma. *Br J Clin Pharmacol* 1988; 26:295–301.
42. Corradi M, Gergelova P, Di Pilato E, *et al.* Effect of exposure to detergents and other chemicals on biomarkers of pulmonary response in exhaled breath from hospital cleaners: a pilot study. *Int Arch Occup Environ Health* 2012; 85:389–396.
43. Tanday S. Epigenetic study identifies genes linked to asthma and allergy. *Lancet Respir Med* 2015; 3:274.
44. Dumas O, Le MN. Do chronic workplace irritant exposures cause asthma? *Curr Opin Allergy Clin Immunol* 2016; 16:75–85.
45. Bello A, Quinn MM, Perry MJ, Milton DK. Characterization of occupational exposure to cleaning products used for common cleaning tasks: a pilot study of hospital cleaners. *Environ Health* 2009; 8:11.
46. Medina-Ramón M, Zock JP, Kogevinas M, *et al.* Short-term respiratory effects of cleaning exposures in female domestic cleaners. *Eur Respir J* 2006; 27:1196–1203.
47. Bernstein JA, Brandt D, Rezvani M, *et al.* Evaluation of cleaning activities on respiratory symptoms in asthmatic female homemakers. *Ann Allergy Asthma Immunol* 2009; 102:41–46.
48. Sastre J, Madero MF, Fernández-Nieto M, *et al.* Airway response to chlorine inhalation (bleach) among cleaning workers with and without bronchial hyperresponsiveness. *Am J Ind Med* 2011; 54:293–299.
49. Tarlo SM, Liss GM. Prevention of occupational asthma. *Curr Allergy Asthma Rep* 2010; 10:278–286.
50. Siracusa A, Desrosiers M, Marabini A. Epidemiology of occupational rhinitis: prevalence, aetiology and determinants. *Clin Exp Allergy* 2000; 30:1519–1534.
51. Heederik D. Cleaning agents and disinfectants: moving from recognition to action and prevention. *Clin Exp Allergy* 2014; 44:472–474.
- This review pointed out the complex mechanism in work-related asthma due to disinfectants and highlighted the relevance of exposure assessment in epidemiological studies in cleaners.
52. Zock JP, Kogevinas M, Sunyer J, *et al.* Asthma risk, cleaning activities and use of specific cleaning products among Spanish indoor cleaners. *Scand J Work Environ Health* 2001; 27:76–81.
53. Rosenman KD, Reilly MJ, Schill DP, *et al.* Cleaning products and work-related asthma. *J Occup Environ Med* 2003; 45:556–563.
54. Medina-Ramón M, Zock JP, Kogevinas M, *et al.* Asthma, chronic bronchitis, and exposure to irritant agents in occupational domestic cleaning: a nested case-control study. *Occup Environ Med* 2005; 62:598–606.
55. Obadia M, Liss GM, Lou W, *et al.* Relationship between asthma and work exposure among nondomestic cleaners in Ontario. *Am J Ind Med* 2009; 52:716–723.
56. Medina-Ramón M, Zock JP, Kogevinas M, *et al.* Asthma symptoms in women employed in domestic cleaning: a community based study. *Thorax* 2003; 58:950–954.
57. 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.

This interesting article suggests that 'environmentally preferable' cleaning products are less harmful, although not risk-free, than traditional cleaning products, indicating that prevention is feasible in cleaning workers.