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Occupational and work-related respiratory disease attributed to cleaning products

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ABSTRACT

Objectives Exposure to cleaning products has been associated with adverse respiratory outcomes. This study aimed to investigate the medically reported incidence, trends in incidence and occupational determinants of work-related respiratory disorders attributed to cleaning agents and to explore the role of 'Quantitative Structure Activity Relationships' (QSAR) in corroborating the identification of chemical respiratory sensitisers.

Methods Respiratory diagnoses attributed to cleaning agents were extracted from The Health and Occupation Research (THOR) surveillance network, 1989–2017. Incidence, trends in incidence and incidence rate ratios by occupation were investigated. Agents were classified by chemical type and QSAR hazard indices were determined for specific organic chemicals.

Results Approximately 6% (779 cases) of the (non-asbestos) THOR respiratory cases were attributed to cleaning agents. Diagnoses were predominantly asthma (58%) and inhalation accidents (27%) with frequently reported chemical categories being aldehydes (30%) and chlorine/its releasers (26%). No significant trend in asthma incidence (1999–2017) was observed (annual average change of −1.1% (95% CI −4.4 to 2.4)). This contrasted with a statistically significant annual decline in asthma incidence (−6.8% (95% CI −8.0 to −5.6)) for non-cleaning agents. There was a large variation in risk between occupations. 7 of the 15 organic chemicals specifically identified had a QSAR generated hazard index consistent with being a respiratory sensitiser.

Conclusion Specific occupations appear to be at increased risk of adverse respiratory outcomes attributed to cleaning agents. While exposure to agents such as glutaraldehyde have been addressed, other exposures, such as to chlorine, remain important. Chemical features of the cleaning agents helped distinguish between sensitising and irritant agents.

Key messages

What is already known about this subject?

► Exposure to cleaning products has been associated with adverse respiratory outcomes including asthma and chronic obstructive pulmonary disease.

What are the new findings?

► Occupational asthma incidence attributed to cleaning agents has not reduced over time; this is in contrast to an overall decline in asthma incidence for non-cleaning agents. A number of occupations, including large occupational groups such as nurses and cleaners, are at increased risk of cleaning agent attributed respiratory disease. A validated structure-activity relationship model can help distinguish between irritant and sensitisation mechanisms for cleaning agent asthma.

How might this impact on policy or clinical practice in the foreseeable future?

► Cleaning agents are an important risk factor for acute respiratory diseases and more needs to be done to manage risks associated with inhalation of chemical agents within cleaning products. This study highlights occupations at increased risk and the types of agents they are exposed to.

INTRODUCTION

Cleaning products are used globally and have been associated with adverse respiratory outcomes including asthma and chronic obstructive pulmonary disease.[1 2] Exposure may occur in both a domestic and/or work environment either via direct use of the cleaning product or as a result of use by others. Studies in Europe and North America of domestic (ie, non-occupational) exposure have linked cleaning products to both an increased risk of new-onset asthma[3] and an increase in symptoms in pre-existing asthmatics.[4 5] In an occupational setting, while certain occupations such as healthcare workers and cleaners and domestics have been highlighted as at increased risk of exposure/adverse health outcomes, the ubiquitous use of cleaning products means that occupational exposure will occur across a broad range of occupations and industries both in the UK and worldwide.[6] As such, a non-trivial proportion of the working population may be at increased risk of adverse health outcomes associated with the use of these products. Identifying and quantifying this 'at risk' proportion of the workforce, including investigating whether there has been any change in risk over time, is important to help inform effective prevention and control measures.

Many different cleaning products are applied in both occupational and domestic settings, encompassing a wide range of chemical agents. Examples of chemical agents commonly used within cleaning products include: alkalis, such as bleach and ammonia; acids, such as acetic acid and aldehydes, such as glutaraldehyde and formaldehyde. Adverse health effects can occur from the individual

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use of such products and from the mixing or joint application of different products, whether accidental or deliberate. As an example, asthmagenic chloramines can be released by the mixing of bleach and ammonia.[7] With new products being developed almost continuously, it is important to be able to categorise these products, based on their chemical components and to determine their irritating and/or sensitising capabilities.

This study aimed to investigate the medically reported incidence, trends in incidence and occupational determinants of work-related respiratory disorders attributed to cleaning agents. As specific low molecular weight (LMW) compounds within a cleaning product are sometimes identified as the cause of work-related asthma, by the reporting physician, another aim of the study was to explore the proportion of such compounds which would be predicted to have respiratory sensitising potential by a validated 'Quantitative Structure Activity Relationship' (QSAR) model.[8] A positive QSAR prediction of respiratory sensitisation potential offers a means of either corroborating the correct identification of a chemical respiratory sensitiser, whereas a negative prediction could suggest that either the reporting physician has incorrectly attributed an asthma case to a certain chemical or that mechanisms other than sensitisation are involved.

METHODS

The study used cases of work-related respiratory disease reported to The Health and Occupation Research (THOR) network.[9] Specifically, we extracted cases reported by chest physicians to Surveillance of Work-Related and Occupational Respiratory Disease (SWORD), by occupational physicians (OPs) to Occupational Physicians Reporting Activity (OPRA) and by general practitioners (GPs) to THOR in General Practice (THOR-GP).

THOR physicians participate either monthly ('core' reporters) or for one randomly selected month each year ('sample' reporters) and report new cases seen during their reporting month and that they believe to have been wholly or partly caused by work.[10–12] For each case, the physician is asked to assign one or more diagnoses and to provide the age, sex, first half of postcode, industry, occupation, causal agent(s) and date of symptom onset. The occupation and industry information is coded using the Standard Occupational and Industrial Classifications,[13 14] while probable causal agents are coded using an in-house coding system developed with the UK Health and Safety Executive.

To identify cases with exposure to cleaning agents, all cases of respiratory disease reported to SWORD (1989–2017), OPRA (1999–2017) and THOR-GP (2006–2017) were extracted and reviewed (figure 1). A cleaning agent was defined as any material used for cleaning and/or disinfecting activities. Exposures arising from specific tasks, such as 'general' cleaning activities, cleaning of medical equipment, cleaning in specialised industrial settings, disinfecting of pool water and cleaning of food or animals were also considered.

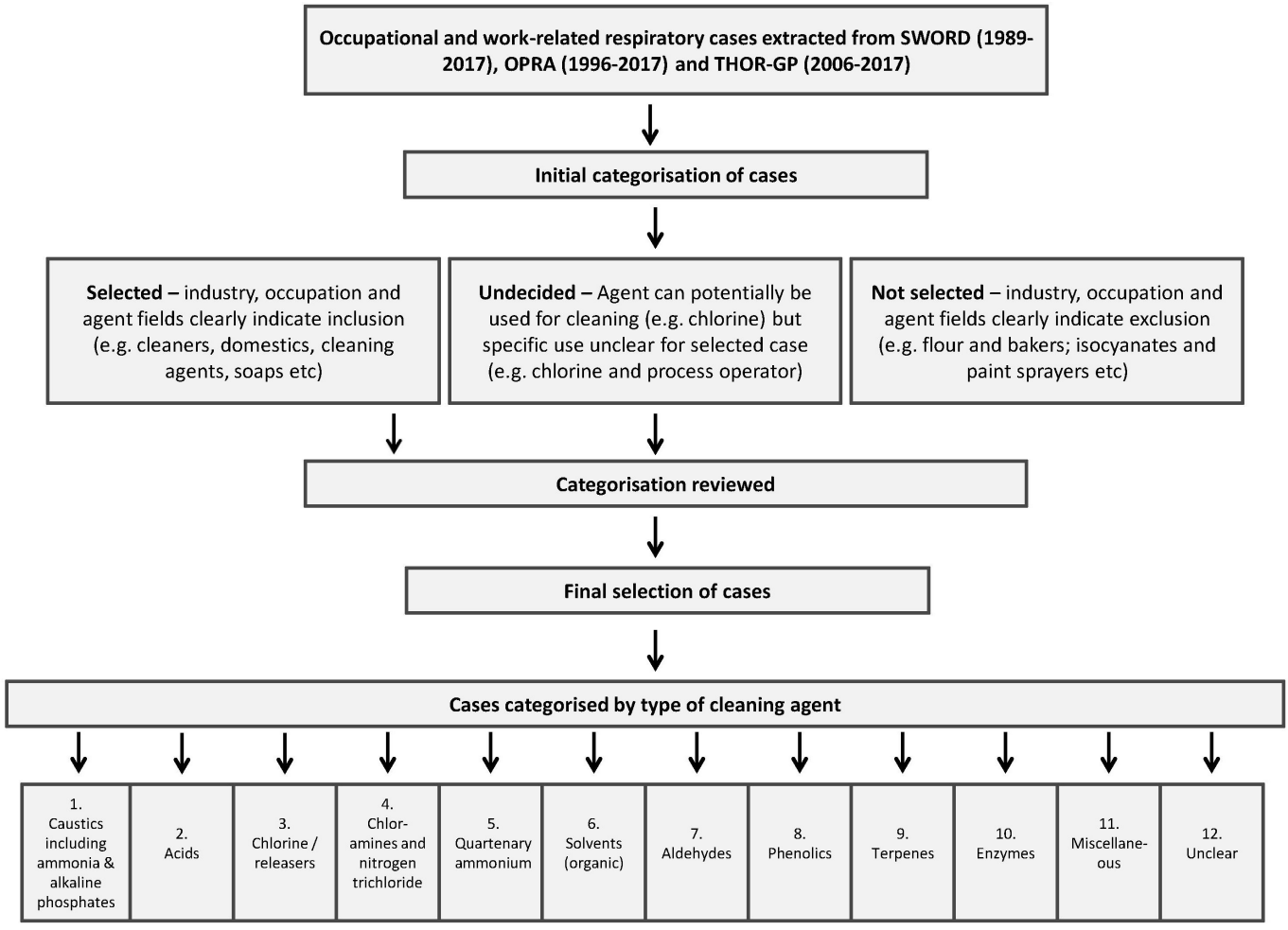

Figure 1 Case selection process and categorisation of agent by taxonomy of cause. SWORD, Surveillance of Work-Related and Occupational Respiratory Disease.

For each category of physicians, cases were initially screened on the likelihood of use of cleaning agents based primarily on information recorded by the physician in the causal agent field and the recorded occupation and industry. The cases and categorisations were then reviewed by two senior research physicians with expertise in respiratory disease and chemical exposures (RA, MS). Cases in the 'undecided' category were only subsequently included if both senior researchers were in agreement.

Cases were then categorised by type of cleaning agent based on a taxonomy, consisting of 12 categories, developed on the basis of chemical class starting from inorganics, through LMW and finally high molecular weight organics. The allocation of cases to these 12 categories was again reviewed by the two senior researchers and any agreed changes implemented.

The actual case reports from 'sample' and 'core' reporters were analysed descriptively by diagnosis, age, sex and agent group. Incidence rate ratios (IRRs) by occupation were calculated for reports to SWORD. In each case, the rate for the specific occupation being considered was compared with the average rate for all remaining occupations combined. The numerator was the average number of estimated cases (ie, 12 × sample cases, +core cases) and the denominator was the average number of persons employed in the UK, according to the Labour Force survey, both for the period 1999–2017.[15] 95% CIs were calculated using a method that allowed for the increased uncertainty generated by sample reporting and included a finite population correction to allow for the fact that only a proportion of eligible UK physicians reported to SWORD.[16]

To investigate trends in incidence based on reports to SWORD (1999–2017), the STATA software command xtnbreg was used to fit a two-level longitudinal, negative binomial (ie, overdispersed) model with random effects. This method allows for variation in the number of reports between chest physicians (e, core versus sample and due to non-response).[17] The dependent variable was the number of actual cases, including zeros, per reporter per month. Calendar time was represented as a continuous variable with a scale of years. Variables representing other potential factors that could influence the reported incidence levels (seasonal variation), first reporting month, reporter type ('core' or 'sample') and an offset variable representing the UK population each year were also included.[17]

The list of cleaning agents reported to have caused at least one case of occupational asthma was scrutinised in order to identify those which were ascribed to a single organic compound of LMW (<1000 Da) with an identifiable molecular structure. Asthma hazard index values, between zero and one representing the estimated probability that a given compound is asthmagenic based on structural features of its molecules, were determined as previously described using the revised QSAR model[8] developed by Jarvis *et al*.[18 19] Hazard index values were then tabulated alongside the compound and the number of reports of asthma. For this revised QSAR an optimal general discriminatory cut-point hazard index of 0.39 has been proposed. If the given LMW compound had a hazard index which was greater than 0.39, it was identified as having the structural requirements to be a respiratory sensitiser.[8]

RESULTS

Approximately 6% (779 cases) of the (non-asbestos) THOR respiratory cases were attributed to cleaning agents. The majority were reported to SWORD (n=690), followed by OPRA (n=73) and THOR-GP (n=16). Cases reported to SWORD and OPRA were predominantly female (67% and 70%, respectively) while cases reported to THOR-GP were predominantly male (56%). The mean age was similar for all three groups (SWORD: 43 years (range 17–75); OPRA: 43 (21-67), THOR-GP: 44 (25-73)). Overall, the most frequently reported chemical categories were aldehydes (30%) and chlorine/its releasers (26%) (table 1). The distribution of the diagnoses found for each agent group is shown in online supplementary table 1.

Table 1 Number (and percentage) of actual cases of occupational and work-related respiratory disease attributed to cleaning agents (by agent group), reported by chest physicians to SWORD* (1989–2017), occupational physicians to OPRA† (1999–2017) and general practitioners to THOR-GP‡ (2006–2017)

		SWORD*	OPRA†	THOR-GP‡
		Total cases (%)		
Group	Name	1989–2017	1999–2017	2006–2017
1	Caustics including ammonia and alkaline phosphates	21 (3%)	4 (5%)	2 (13%)
2	Acids	39 (6%)	6 (8%)	1 (6%)
3	Chlorine/releasers	167 (24%)	30 (41%)	6 (38%)
4	Chloramines and nitrogen trichloride	27 (4%)	2 (3%)	0
5	Quaternary ammonium	9 (1%)	2 (3%)	0
6	Solvents (organic)	45 (7%)	0	1 (6%)
7	Aldehydes	223 (32%)	11 (15%)	1 (6%)
8	Phenolics	7 (1%)	2 (3%)	0
9	Terpenes	4 (1%)	0	2 (13%)
10	Enzymes	6 (1%)	1 (1%)	0
11	Miscellaneous	27 (4%)	5 (7%)	1 (6%)
12	Unclear	115 (17%)	12 (16%)	2 (13%)
	Total cases§	690 (100%)	73 (100%)	16 (100%)

*Surveillance of Work-Related and Occupational Respiratory Disease.
†Occupational Physicians Reporting Activity.
‡The Health and Occupation Research network in General Practice.
§A case may be attributed to more than one cleaning agent.

The 690 SWORD cases resulted in 702 diagnoses (a case can have more than 1 diagnosis), comprising: asthma (418; 60%), inhalation accidents (195, 28%), rhinitis (35; 5%), other respiratory disease (35; 5%), bronchitis/emphysema (12; 2%) and allergic alveolitis (7; 1%). The 35 cases reported as other respiratory disease included a range of miscellaneous diagnoses including upper airways irritation (4 diagnoses), hyperventilation (3), anaphylaxis (2) and reactive airways dysfunction syndrome (RADS) (2).

The 73 OPRA cases resulted in 73 diagnoses comprising asthma (35 diagnoses), inhalation accidents (16), rhinitis (2) and bronchitis/emphysema (1). The remaining 21 cases reported under the category other respiratory disease had a range of miscellaneous diagnoses including 7 cases of RADS.

Of 16 cases reported to THOR-GP, only five had specific diagnoses: three cases of inhalation accident and two cases of asthma. The remainder were either reported as symptoms or 'other respiratory disease'.

SWORD cases were predominantly reported in health and social care (47% of the 690 cases) and manufacturing (11%). Frequently reported occupations were nurses, nursing auxiliaries and assistants (33% of the 690 cases), cleaners (20%), sports and leisure assistants, sports coaches, instructors and officials (6%), food, drink and tobacco process operatives (3%) and elementary process plant occupations (3%). For OPRA, health and social care was the most frequently reported industry (66% of cases) with

Table 2 Actual and estimated cases and incidence rate ratios (plus 95% CI) by occupation for occupational and work-related (total) respiratory disease and for asthma, attributed to cleaning agents, as reported by chest physicians to SWORD*, 1999–2017

	Actual (estimated) cases		IRR (95% CI)†	
Occupation	All respiratory diagnoses	Asthma	All respiratory diagnoses	Asthma
launderers, dry cleaners, pressers	4 (26)	2 (13)	39.7 (19.3 to 81.4)	20.2 (7.3 to 55.7)
Housekeepers and related occupations	6 (17)	6 (17)	26.1 (11.3 to 60.5)	29.3 (12.6 to 67.8)
Cleaners	56 (177)	45 (166)	20.5 (15.4 to 27.3)	21.9 (16.1 to 29.7)
Sports and leisure assistants, sports coaches, instructors and officials	17 (39)	10 (32)	16.4 (10.3 to 26.0)	14.4 (8.2 to 25.4)
Food, drink and tobacco process operatives	10 (43)	5 (38)	14.2 (8.2 to 24.5)	14.1 (7.7 to 25.9)
Medical and dental technicians, dental nurses	7 (18)	7 (18)	12.3 (5.7 to 26.8)	13.8 (6.3 to 30.0)
Nurses, nursing auxiliaries and assistants	67 (89)	60 (82)	6.8 (5.2 to 8.9)	7.0 (5.2 to 9.4)
Elementary process operations	8 (30)	7 (29)	5.4 (2.9 to 10.0)	5.8 (3.1 to 11.1)
Chefs, cooks, kitchen and catering assistants	8 (19)	4 (15)	1.4 (0.7 to 2.9)	1.2 (0.5 to 3.0)
Teachers	7 (18)	7 (18)	0.7 (0.3 to 1.4)	0.7 (0.4 to 1.6)
Care assistants and home carers	5 (5)	5 (5)	0.3 (0.2 to 0.6)	0.4 (0.2 to 0.6)
Total cases	251 (592)	201 (531)	/	/

*Surveillance of Work-Related and Occupational Respiratory Disease.
†The reference category was the average rate for all remaining occupations combined.
IRR, incidence rate ratio.

frequently reported occupations being nurses, nursing auxiliaries and assistants (32% of the 73 cases) and cleaners/domestics (19%). Frequently reported occupations for THOR-GP included cleaners/domestics (five cases) and launderers, dry cleaners, pressers (three cases).

Based on SWORD cases (1999–2017), a large variation in risk was observed with the IRRs suggesting the highest risk occupation to be 'launderers, dry cleaners and pressers' for whom the incidence was approximately 40 times the average of all other occupations compared with elementary process occupations which had a risk of 5 times the average of all other occupations (table 2 and figure 2). Restricting the analysis to asthma diagnoses (table 2) changed the occupation rankings slightly but the highest risk occupation was still 'launderers, dry cleaners and pressers' (although this estimate was based on a relatively small number of cases).

The proportion of cases attributed to aldehydes in chest physician reports to SWORD has decreased over time while other groups, for example, chlorine/releasers, have maintained or increased their relative contribution over the same period (online supplementary table 2). Assuming a linear trend, a non-statistically significant annual average change in incidence in respiratory disease attributed to cleaning agents (as reported to SWORD) of −1.8% (95% CI −4.8 to 1.3) was observed (1999–2017). Restricted to asthma diagnoses, the equivalent figure was −1.1% (95% CI −4.4 to 2.4). In contrast, the trend for all other, that is, non-cleaning agents (data not shown) showed a statistically significant annual decline at −5.0% (95% CI −5.9 to −4.0) for total (excluding asbestos) respiratory disease and −6.8% (95% CI −8.0 to −5.6) for asthma. Excluding aldehydes resulted in an annual average *increase* of 2.7% (95% CI −0.8 to 6.4) for total respiratory disease and 3.6% (95% CI −0.3 to 7.7) for asthma,

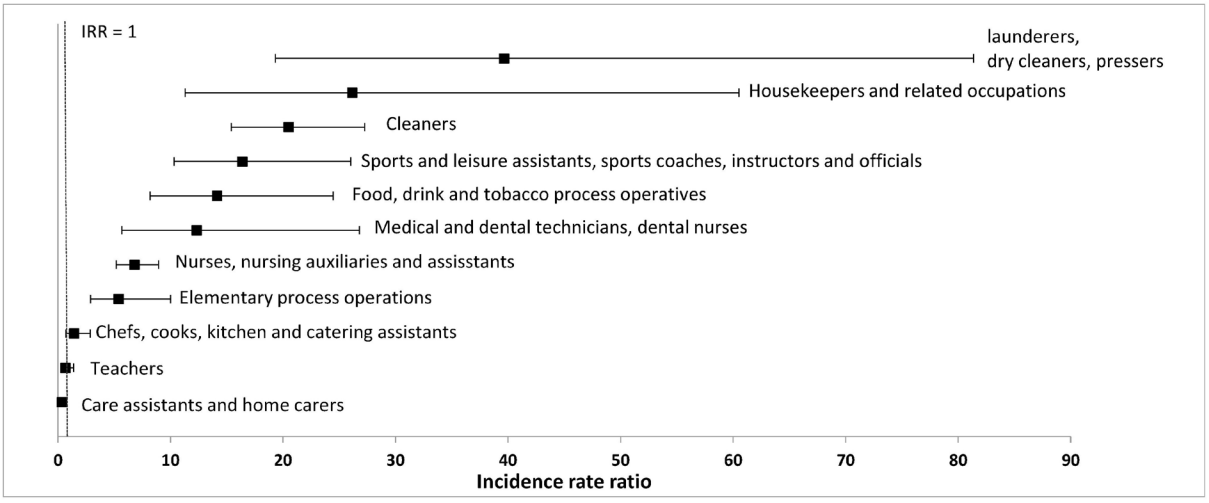

Figure 2 Incidence rate ratios for occupational and work-related respiratory disease attributed to cleaning agents, by occupation, as reported by chest physicians to SWORD,1996–2017. SWORD, Surveillance of Work-Related and Occupational Respiratory Disease.

Table 3 QSAR generated hazard indices with case numbers for specific LMW organic compounds identified as the likely causative agent of occupational asthma attributed to cleaning agents reported by chest physicians to SWORD* (1989–2017), occupational physicians to OPRA† (1999–2017) and general practitioners to THOR-GP‡ (2006–2017)

Chemical name	Asthma hazard index§	Number of reported cases of OA
Chlorhexidine	1	1
Formaldehyde	1	3
Diethanolamine	0.88	1
Glutaraldehyde	0.6	172
Ethanolamine	0.56	1
(Sodium) dichloroisocyanurate	0.49	3
Ethylene diamine	0.49	1¶
Xylenone	0.26	1
Acetic acid	0.19	1
Benzalkonium (chloride)	0.18	3
Didecyldimethylammonium (chloride)	0.18	1
Peracetic acid	0.07	5
Perchloroethylene	0.07	2
Dichloromethane	0.05	1
1,1,1-trichloroethane	0.05	1

*Surveillance of Work-Related and Occupational Respiratory Disease.
†Occupational Physicians Reporting Activity.
‡The Health and Occupation Research network in General Practice.
§Using the 2015 version of Jarvis *et al* QSAR (cut-point 0.39: if the given LMW compound had a hazard index which was greater than 0.39 it was identified as having the structural requirements to be a respiratory sensitiser).
¶Anaphylaxis.
LMW, low molecular weight; QSAR, Quantitative Structure Activity Relationship.

both of which were significantly different to the declining trends observed for all other, that is, non-cleaning (excluding asbestos) agents ($p<0.001$).

Restricting analyses to occupational asthma (455 cases in total), 15 specific LMW chemicals were identified as having been the attributed cause of at least one case of occupational asthma, listed in table 3 alongside the QSAR generated hazard index for each compound. For seven of these 15 compounds, the QSAR generated hazard index is greater than the cut-point of 0.39.

DISCUSSION

Reports by chest physicians, OPs and GPs to the UK-wide surveillance system, THOR, suggest that 6% of the (non-asbestos related) cases of work-related respiratory disease were wholly or partly caused by exposure to 'cleaning agents'. Diagnoses were primarily asthma (58%) and inhalation accidents (27%) and frequently reported agents were aldehydes and chlorine releasers (with some variation in the relative proportions of the 12 agent groups over time). Certain occupational groups had a particularly high incidence of cleaning agent attributed respiratory disease. Incidence overall (all occupations combined) did not exhibit any significant trend during the study period. Of the 15 specific LMW chemicals identified from the likely causative agents for (cleaning related) asthma reports to THOR, 7 had a QSAR generated hazard index suggesting their mechanism of asthmagenesis is likely to involve sensitisation. Six of these seven compounds are listed as recognised respiratory sensitisers by the North American Association of Occupational and Environmental Clinics.[20]

The proportion of cases attributed to 'cleaning agents' is consistent with observations from other surveillance systems with 9% and 12% of occupational asthma cases attributed to cleaning agents by a voluntary physician based system in Catalonia (Spain) and the work-related asthma surveillance programme in Michigan (USA), respectively.[21 22] Our data also suggested that there has been no significant change in the incidence of work-related respiratory disease attributed to cleaning agents during 1999–2017. However, if aldehydes are excluded (for which we know a reduction in incidence has occurred), the data suggested an increase in incidence over the same period and which was significantly different from the decreasing trend observed for all other non-cleaning agents. Elsewhere, a study in France demonstrated a statistically significant increase in incidence of work-related asthma attributed to quaternary ammonium compounds (QACs) and a slight (but non-significant) increase attributed to other cleaning products.[23] There have been 11 THOR reports of work-related respiratory disease attributed to QACs, with 10 of these reported since 2002. It will be of interest to continue to monitor SWORD trends and as the database of reported cases increases to investigate trends separately for specific cleaning agents.

'Launderers, dry cleaners and pressers' had the highest risk (compared with all other occupations) of work-related respiratory disease attributed to cleaning agents. However, this estimate was based on a relatively small number of cases. SWORD reports for this group included inhalation accidents attributed to dry cleaning agents notably perchloroethylene, a solvent that has been linked to many adverse health effects[24] while the reported agents for asthma included glutaraldehyde, detergent/enzymes and chloramines. The link between glutaraldehyde and asthma is well-established[25] and this association is supported by the high QSAR hazard index and the high number of reports to THOR. Enzymes and other components of detergents (eg, added fragrances) are also recognised asthma sensitisers/irritants.[26]

Exposure to chloramines has been linked to adverse respiratory effects among swimming pool attendants/instructors whereby exposure occurs through the reaction of chlorine with substances such as urine and sweat.[27] A relatively high IRR for this group of workers (categorised under sports and leisure assistants, sports coaches, instructors and officials) was observed in this study. Of the 17 SWORD cases reported for this group (1999–2017), 9 were attributed to exposure to chloramines (with the exposure for the remainder recorded by the physician as 'chlorine'). A recent paper has suggested that similar exposure mechanisms to chloramines (ie, through the mixing of chlorine with urine/sweat) may be linked to asthma in other groups of workers such as cleaners and healthcare workers.[7] Although the majority of the SWORD chloramine cases were attributed to swimming pool exposures, other occupations were reported including healthcare workers, cleaners and food preparers. In general, chlorine or chlorine releasers were the second most frequently reported group of 'cleaning agents' associated with THOR respiratory cases. This group encompassed a wide range of products with associated reports to THOR in 30+ different occupations. Chlorine itself is irritant to the respiratory tract and is well recognised as one of the causes of RADS.[28]

There were 46 THOR case reports for which solvents had been identified as the likely cause of adverse respiratory effects, most commonly inhalation accidents (57%), but in 14 cases, asthma was the reported diagnosis. While it was often not possible to identify specific solvents from the information provided by the physician, it was possible to apply the QSAR model to three specific solvents reported to have caused asthma:

perchloroethylene, dichloromethane and 1,1,1-trichloroethane. For all three, the hazard index was very low (<0.1), suggesting that it is unlikely that these agents are respiratory sensitisers. One possibility is that these cases of asthma were caused by other agents but were misattributed (by the physicians and/or workers) to the solvents. It is also possible that these agents cause asthma by irritant mechanisms.

This study also observed an increased risk in work-related respiratory disease attributed to cleaning agents in specific groups of healthcare workers: nurses, nursing auxiliaries and assistant, medical and dental technicians and dental nurses. A large proportion (~80%) of these cases was attributed to aldehydes (glutaraldehyde) although the proportion attributed to this agent group decreased over time. We have previously demonstrated (using SWORD data) a reduction in asthma incidence from glutaraldehyde exposure as a result of UK government interventions,[29] the last case report having been in 2006. Chlorine/its releasers were the second most frequently reported agent group for healthcare workers. As already discussed the chlorine released can cause asthma by a variety of potential mechanisms. It is also theoretically possible that the chlorine releasing agent itself could act as a respiratory sensitiser, as supported in the case of dichloroisocyanurate by a QSAR generated hazard index of 0.49.

The majority of the respiratory 'cleaning agent' cases reported to THOR-GP were reported as 'symptoms' (eg, wheeze, throat/nose irritation, cough and so on) rather than as a specific diagnosis (eg, asthma). This is indicative of the reporting of respiratory cases to THOR-GP in general, whereby GPs often stop short of providing an actual diagnosis (particularly regarding asthma-like symptoms). Referral guidelines provided by the British Thoracic Society (BTS) advise referral if, for example, there is doubt about a diagnosis of asthma or there is the need to confirm/rule out occupational asthma.[30] However, less than half of the cases seen by the GPs were referred to secondary care, perhaps suggesting that referral guidelines are not being fully realised.

One limitation of the present study was the identification of cases for inclusion, particularly for chemicals that have uses other than cleaning (eg, solvents). It is possible that cases may have been wrongly included or excluded. However, the consideration of occupation/industry information (as well as agent) in the selection process should have minimised any errors. It is also possible that an individual case may have been reported to more than one THOR scheme (reports to THOR are pseudoanonymised and contain no unique identifiers to enable cross-comparison). However, given the relatively low numbers of respiratory diagnoses reported to OPRA and THOR-GP, any degree of overlap is likely to be minimal. There may also have been misattribution (eg, of cause or job) by the reporting physician. Since the criteria for reporting to THOR are fairly inclusive, some of the reported associations may have arisen from coexposures and/or misclassification of the true cause. It is also likely that relevant cases are under-reported to THOR either because physicians do not participate in THOR or because those that do participate do not report everything they see. While it is possible to make adjustments for factors such as these to help improve the accuracy of (absolute) incidence rates,[31] in this study (where the objective was to compare risk between industries), we chose instead to estimate IRRs, thus mitigating the impact of the uncertainty in the denominator.[16]

In conclusion, this study has highlighted the main occupations affected by work-related ill-health due to cleaning agents. Occupational asthma was the most frequently reported diagnosis with both sensitisation and non-sensitisation mechanisms being suggested by structural analysis of specific causative chemicals. Importantly, this study has also shown that the risk for respiratory disease due to cleaning products does not appear to be declining (in particular, after excluding aldehydes). This is in contrast to trends for work-related respiratory disease overall which suggest a decline in incidence over the study period. This demonstrates the need for interventions to reduce worldwide exposure to and health risks arising from cleaning agents.

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