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Development of a job-task-exposure matrix to assess occupational exposure to disinfectants among US nurses

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ABSTRACT

Objectives Occupational exposure to disinfectants is associated with work-related asthma, especially in healthcare workers. However, little is known about the specific products involved. To evaluate disinfectant exposures, we designed job-exposure (JEM) and job-task-exposure (JTEM) matrices, which are thought to be less prone to differential misclassification bias than self-reported exposure. We then compared the three assessment methods: self-reported exposure, JEM and JTEM.

Methods Disinfectant use was assessed by an occupational questionnaire in 9073 US female registered nurses without asthma, aged 49–68 years, drawn from the Nurses' Health Study II. A JEM was created based on self-reported frequency of use (1–3, 4–7 days/week) of 7 disinfectants and sprays in 8 nursing jobs. We then created a JTEM combining jobs and disinfection tasks to further reduce misclassification. Exposure was evaluated in 3 classes (low, medium, high) using product-specific cut-offs (eg, <30%, 30–49.9%, ≥50%, respectively, for alcohol); the cut-offs were defined from the distribution of self-reported exposure per job/task.

Results The most frequently reported disinfectants were alcohol (weekly use: 39%), bleach (22%) and sprays (20%). More nurses were classified as highly exposed by JTEM (alcohol 41%, sprays 41%, bleach 34%) than by JEM (21%, 30%, 26%, respectively). Agreement between JEM and JTEM was fair-to-moderate (κ 0.3–0.5) for most disinfectants. JEM and JTEM exposure estimates were heterogeneous in most nursing jobs, except in emergency room and education/administration.

Conclusions The JTEM may provide more accurate estimates than the JEM, especially for nursing jobs with heterogeneous tasks. Use of the JTEM is likely to reduce exposure misclassification.

WHAT THIS PAPER ADDS

- Assessment of occupational exposure to specific disinfectants is an essential step to evaluate their role in respiratory health. Development of accurate methods of assessment is needed.
- In a study of 9073 registered nurses, use of disinfectants varied widely according to nursing jobs and related cleaning tasks.
- We developed a nurse-specific job-task-exposure matrix (JTEM) to assess occupational exposure to disinfectants, by taking into account variability of exposure in a given job.
- The JTEM is likely to reduce exposure misclassification compared with a job-exposure matrix (JEM), especially for jobs with heterogeneous tasks.

INTRODUCTION

Hospital workers, and particularly nurses, are highly exposed to cleaning and disinfecting products both in frequency and intensity.^{1,2} To protect patients from healthcare-associated infections, various types of disinfectants are used by healthcare and cleaning workers.³ The application of infection prevention guidelines has meant that healthcare workers commonly engage in cleaning and disinfection tasks⁴ including the use of products in spray form.^{3,5} Cleaning and disinfecting products are complex mixtures of many chemical components, some of which can cause or exacerbate asthma.³ Ammonia, bleach, glutaraldehyde, ortho-phthalaldehyde or quaternary ammonium compounds (quats) are common chemicals found in cleaning products or disinfectants.^{1,4,6} Several studies have shown associations with onset or symptoms of asthma but little is known about specific agents involved,^{2,3,7} which limits the development of disease prevention strategies.⁸ Indeed, identifying which specific agents might affect the respiratory health of healthcare workers is challenging,^{4,9} partly due to the lack of suitable exposure assessment methods. Among the methods used in epidemiological studies, self-report is the most common, especially to evaluate exposure to specific agents (eg. ammonia, bleach). Self-reported exposure may be affected by information biases¹⁰ (memory, misclassification) with a potentially differential misclassification between asthmatic and non-asthmatic individuals.^{1,10,11} In a study by Donnay *et al*,¹ the use of cleaning products and disinfectants in hospital workers was significantly under-reported when compared with expert assessment. The expert assessment method provides exposure estimates at the individual level and thus takes into account variability of exposure between individuals in the same job, but is not practical in the

large surveys needed to investigate the asthma risk of specific cleaning and disinfecting agents. Assessment of exposure by a job-exposure matrix (JEM) is less prone to differential misclassification bias than self-report and is a low-cost exposure assessment method, but attributes the same exposure to all the workers in a given job,^{10,11} and thus does not take into account the variability of exposure between workers within the same occupation.¹² Occupational exposure may be heterogeneous for a given occupation according to the tasks performed. Several authors underlined the importance of taking into account the tasks to reduce exposure misclassification,^{9,13} leading to the emergence of the task-exposure (TEM) and job-task-exposure (JTEM) matrices, mainly in cancer epidemiology.^{9,12,14,15} To the best of our knowledge, no JEM, TEM or JTEM is available to evaluate exposure to the specific agents or compounds of cleaning products and disinfectants. Using occupational exposure data collected in 9073 US registered nurses from the Nurses' Health Study II (NHSII), we aimed to design nurse-specific JEM and JTEM to evaluate exposure to cleaning products and disinfectants. In addition, we compared exposure assessment based on self-report, JEM and JTEM. Our hypothesis was that important variability in exposure would be observed within jobs according to tasks performed, making the JTEM a probably better method for the assessment of occupational exposure than the JEM.

METHODS

Population

The NHSII^{16,17} is an ongoing prospective study which began in 1989 when 116 430 registered female nurses aged 25–44 years, from 15 US states, completed a mailed questionnaire on their medical history, lifestyle characteristics and nursing job types. Every 2 years, follow-up questionnaires were sent to update information on potential risk factors, identify newly diagnosed diseases and nursing jobs. Since 2009, nurses have been asked two questions on the frequency of instrument disinfection and surface cleaning tasks.⁶

In 2014, we initiated a nested case–control study on asthma. In order to evaluate exposure to specific disinfectants among nurses, an occupational questionnaire was sent to nurses with and without asthma. In the current study to design JEMs and JTEMs, to avoid differential misclassification of exposure, we selected at random a sample of 12 280 non-asthmatic nurses (see online supplementary figure E1) out of those who never reported asthma (from 1989 to 2011; n=94 758) and who were still in a nursing job at the time of the 2011 follow-up questionnaire. Out of 12 280 non-asthmatic nurses, 10 189 were selected among all types of nursing jobs and an additional sample of 2091 nurses (enriched sample) was selected among operating room (OR), emergency room (ER) and intensive care unit (ICU) nurses in order to enrich the sample of less frequent nursing jobs with expected high exposure levels. The NHSII study and the current investigation were approved by the Institutional Review Board at the Brigham and Women's Hospital (Boston, Massachusetts, USA).

[SUPPLEMENTARY DATA]

Current job, disinfecting tasks and use of disinfectants

The 2014 occupational questionnaire was adapted to the US context from a questionnaire used in the European Community Respiratory Health Survey

(ECRHS)¹⁸ and the Epidemiological Study on the Genetics and Environment of Asthma, Bronchial Hyper-responsiveness and Atopy (EGEA).¹

Data on current nursing job was collected in the 2014 occupational questionnaire by the question ‘Which best describes your current employment status?’, with eight categories provided: nursing in the ER, OR, ICU, other inpatient nurse, outpatient or community, other hospital nursing, nursing outside hospital and nursing education or administration (see question 1 on online supplementary figure E2). Two questions (4 and 5, see online supplementary figure E2) regarding the frequency (days/week) of the main disinfecting tasks performed at work were also included: ‘Thinking about your current job and the use of disinfectants (such as ethylene oxide, hydrogen peroxide, ortho-phthalaldehyde, formaldehyde, glutaraldehyde and bleach): (a) On how many days per week, on average, do you clean medical instruments with disinfectants? (b) On how many days per week, on average, do you clean surfaces (like floors, tables) at work with disinfectants? (never, <1, 1–3, 4–7 days/week)’.

These tasks were chosen based on results from the Texas healthcare workers study,⁶ which suggested that they were the most relevant in terms of asthma risk.

Finally, questions were asked about the frequency of use (‘On how many days per week do you use the following disinfectants at work?’; see questions 14a–14p, online supplementary figure E2) of 14 specific disinfectants (eg, glutaraldehyde, bleach, quats). Participants could fill in the brand name of the products they used if they did not know the active compound. We searched the safety data sheets of all provided brand names to determine the products’ main active compounds. Self-reported exposure to each specific disinfectant was evaluated using a crude report and this additional information, and was considered in most analyses as binary variables according to weekly use (1–3 or 4–7 vs never or <1 day/week).

JEM and JTEM

Current job and use of disinfectant were used to design JEMs and JTEMs by three methods based on weekly use of products (yes/no), frequency (days/week) and/or intensity (hours/day) of exposure (see online supplementary table E1 and figure E2). To create JTEMs, the two questions on disinfecting tasks (to clean medical instruments/to clean surfaces) were combined to create a three-category variable, to define tasks performed weekly: no weekly disinfection tasks; weekly use of disinfectants to clean surfaces only; and weekly use of disinfectants to clean at least medical instruments (regardless of the use of disinfectants to clean surfaces). The category ‘clean instruments only’ was not studied separately because of the low number of participants in this category (2.9%); it was thus grouped with the category ‘clean instruments and surfaces’ into the larger category ‘clean at least instruments’. The first method to generate the JEM and JTEM was based on the percentage of participants reporting exposure to a given disinfectant in a given nursing job (JEM) or for a given nursing job and task category (JTEM).^{19,20} The job axis of the JEM included the eight types of nursing jobs (OR, ER, ICU...). The ‘job-task’ axis of the JTEM included the 24 possible combinations of eight types of nursing jobs by three categories of cleaning tasks (surfaces only, at least instruments, none). For the exposure axis of the JEM and JTEM, the 14 disinfectants and the general use of sprays were considered. However, only seven disinfectants for which at least 10% of the nurses in at least one nursing job reported weekly exposure (alcohol, hypochlorite bleach, peroxide bleach, glutaraldehyde, quats, enzymatic cleaners, formaldehyde), and sprays, were retained. The other seven disinfectants (acetic acid, ammonia,

chloramine T, ethylene oxide, ortho-phthalaldehyde, peracetic acid, phenolics) were grouped together as 'other' (with requirement of exposure to at least 1 of these agents) since <10% of the women reported exposure, regardless of the nursing job. The second method was based on a score (range 0–6) combining frequency (0: <1; 1: 1–3; 2: 4–7 days/week) and intensity (1: <1; 2: 1–4; 3: >4 hours/day) of exposure, evaluated by the following questions 'On how many days per week do you use the following disinfectants at work?' for frequency and 'On days with disinfectant use, how many hours, on average, do you use disinfectants' for intensity. The score was calculated for each nurse with the assumption that intensity was the same for all disinfectants used. The third method was based on a weighted score according to the frequency of exposure to specific chemicals using the percentage of self-reported exposure weighted by 2 (1–3 days/week) and 5 (4–7 days/week). The second and third methods for both the JEM and JTEM are detailed online (see online supplementary table E1).

Specific cut-offs were defined to classify exposure in 'low', 'medium' and 'high' levels for each disinfectant and each method developed (see online supplementary table E2). Cuts-offs were chosen according to the distribution of the exposure prevalence (eg, percentage of nurses reporting weekly exposure; figure 1) over the 24 categories defined by job types and cleaning tasks (ie, 8 job types by 3 tasks) for each disinfectant. For a given method, the same cut-offs were used for the JEM and the JTEM. The first quartile (Q1) and median were used to define cut-offs for low and high exposure, respectively. For some chemicals, Q1 and the median were very low and minimum cut-offs were defined as follows: for the first method, we chose the maximal value between the median and 10% to define the cut-off for high-level exposure; and the maximal value between Q1 and 5% to define the cut-off for low-level exposure. Indeed, we considered that classifying a job as 'highly' exposed to a specific disinfectant was not realistic if <10% of nurses in this job reported being exposed. Similarly, classifying a job as 'moderately' exposed to a specific disinfectant was not realistic if <5% of nurses in this job reported being exposed.

[FIGURE 1]

Statistical analyses

Exposures evaluated by the JEM were compared with those evaluated by the JTEM, and both were compared with self-reported exposure alone. Specificity and sensitivity were computed for each exposure considering the JTEM as the reference, according to our a priori hypothesis. Both Cohen's κ (chance-corrected) and Phi (chance-independent) coefficients were calculated to evaluate agreement between JEM and JTEM, as previously suggested.¹⁰ To interpret strength of the agreement, standard cut-offs (poor: <0; slight: 0–0.2; fair: 0.2–0.4; moderate: 0.4–0.6; substantial: 0.6–0.8; and almost perfect: 0.8–1) were used.²¹ Differences between JEM and JTEM assessment were tested by the McNemar test.

In addition, sensitivity analyses were performed by stratifying analyses on age (49–54; 55–59; ≥ 60 years).

All analyses were performed with SAS V.9.3 (Cary, North Carolina, USA).

RESULTS

Description of the study population

Out of 12 280 nurses invited, 11 134 (91%) completed the 2014 occupational questionnaire. After excluding 2061 women (2057 not in a nursing job in 2014; 4 declined study), the study population included 9073 non-asthmatic women (see online supplementary figure E1).

The nurses were on average 59 years of age (SD 4; range 49–68), with slightly younger nurses in the enriched sample (table 1). In the random sample, 3% of the nurses worked in the ER, 6% in the OR and 5% in the ICU. Most nurses reported working in outpatient or community (23%) and in nursing education or administration (16%) nursing categories. Fifty-four per cent of nurses reported that they cleaned surfaces with disinfectants weekly, while 21% cleaned instruments with disinfectants weekly. Fifty-five per cent of nurses reported using at least 1 of the 14 specific disinfectants weekly, 11% used them at least 1 hour/day and 20% performed only administrative tasks (table 1). Across nursing jobs, the percentage of nurses using disinfectants 4–7 days/week ranged from 5% to 48%, while weekly use ranged from 19% to 88% (see online supplementary table E3). Nurses in the ER, OR and ICU more often used disinfectants weekly to clean instruments or surfaces (>80%), as compared with other nursing jobs.

[TABLE 1]

The most frequently reported disinfectants were alcohol (weekly use: 39%), hypochlorite bleach (22%) and sprays (20%) (figure 2). These agents were followed by quats (14%), peroxide bleach (9%), glutaraldehyde (7%), formaldehyde (5%) and enzymatic cleaners (4%).

[FIGURE 2]

Definition of cut-offs used to design the JEM and JTEM

The distribution of self-reported occupational exposure varied widely according to disinfectants (figure 1). Therefore, product-specific cut-offs were defined as described in Methods section and online supplementary table E1. For example, for alcohol, Q1 was 30.0 and median was 49.5; a nursing job in which <30% of the nurses reported weekly exposure was thus classified as 'low exposure', between 30% and 49.9% as 'medium exposure' and more than 50% as 'high exposure' (see online supplementary table E2). For other disinfectants, exposure levels were similarly assigned based on product-specific Q1 and median. For glutaraldehyde, enzymatic cleaners, peroxide bleach and formaldehyde, values of Q1 and median were very low (<5% and 10%, respectively; figure 1), and minimum cut-offs were used.

JEM and JTEM design

The JEM and JTEM design strategies are presented in table 2 (examples) and online supplementary table E4 (full matrices). Self-reported exposures varied considerably according to nursing jobs and tasks. Among ER nurses, 38% reported weekly use of hypochlorite bleach and were classified as highly exposed by the JEM (table 2). OR nurses reported less use of hypochlorite bleach (24%) than ER nurses and were classified with medium exposure by the JEM. Exposures within a job also varied according to disinfecting tasks. For example, OR nurses were assigned a low exposure level to hypochlorite bleach when they performed no cleaning tasks

(weekly use reported by 9% of the nurses); those who cleaned only surfaces (weekly use: 24%) were assigned a medium exposure level to hypochlorite bleach; and nurses who cleaned at least instruments (weekly use: 36%) were assigned a high exposure level.

[TABLE 2]

Comparison of self-report, JEM and JTEM exposure assessments

More nurses were classified as exposed overall (ie, medium or high exposure) by the JEM (alcohol 84%, hypochlorite bleach 84%, sprays 84%) and JTEM (62%, 62% and 59%, respectively) than by self-report. In addition, more nurses were classified highly exposed by the JTEM (41%, 34% and 41% for alcohol, hypochlorite bleach and sprays, respectively) than by the JEM (21%, 26% and 30%, respectively; figure 2).

JEM and JTEM estimates of exposure were heterogeneous for most nursing jobs and disinfectants, except for nurses working in the ER and in education or administration (eg, 89% and 81% classified similarly by the JEM and the JTEM for hypochlorite bleach, respectively; see online supplementary table E5). For exposure to formaldehyde, JEM and JTEM estimates were similar.

Comparing high versus medium/low exposure, more nurses were classified highly exposed by the JTEM than by the JEM, whereas the opposite was observed comparing high/medium versus low exposure (table 3). For alcohol, for example, 21% of the nurses were classified as high exposure with the JEM, versus 41% with the JTEM; however, 84% were classified as high/medium exposure with the JEM and 62% with the JTEM. For most disinfectants, except enzymatic cleaners and formaldehyde, the JTEM classified more nurses in the low and high categories, whereas the JEM classified more nurses in the intermediate category (figure 2). Agreement between the JEM and JTEM was fair-to-moderate (κ coefficient 0.3–0.5) for all disinfectants except for formaldehyde (0.8). Phi coefficients were slightly higher than κ coefficients for all disinfectants.

[TABLE 3]

Sensitivity analyses

Using methods 2 and 3 to design the JEM and JTEM, exposure assessments were mostly similar to those observed with method 1. We observed discordance between the three methods for peroxide bleach, glutaraldehyde and formaldehyde (2/0/1) for some nursing jobs (see online supplementary table E6).

Self-report, JEM and JTEM exposure assessment were stratified according to three age categories (49–54/55–59/ ≥ 60 years). Older nurses were less often classified highly exposed than younger nurses by the JEM and the JTEM, consistently with self-report assessments (see online supplementary table E7).

DISCUSSION

In a study of 9073 registered nurses, we found strong heterogeneity in exposure to specific disinfectants, according to both nursing jobs and instrument/surface cleaning tasks. Weekly use of disinfectants to clean surfaces or instruments was commonly reported, especially among nurses working in the ER, OR and ICU. We developed a nurse-specific JTEM to assess occupational exposure to disinfectants by taking into

account the observed variability of exposure in a given job. These results suggest that the JTEM may be the preferred method to assess occupational exposure to disinfectants among nurses, compared with the JEM or self-report. The JTEM is likely to reduce exposure misclassification compared with the JEM, especially for jobs with heterogeneous tasks.

Exposure assessment

Exposure assessment is a crucial step to obtain reliable results when studying associations with the disease.¹³ Several methods were developed to assess occupational exposure to cleaning and disinfecting products but none is optimal. The expert method, which is often considered to be the most accurate method for retrospective exposure assessment, takes into account individual occupational information (tasks, specific exposure).^{1,22} However, this method is lengthy, expensive, depends on the competency of the expert and is not practical for large epidemiological studies; moreover, this method is not reliable for all hazards.¹ Self-reported exposure is a simple method that allows variations in exposure within job titles¹¹ and is easily applied in large epidemiological studies. However, reporting or recall bias might be present and lead to differential misclassification.¹¹ In this study, results showed lower prevalence of most self-report exposures compared with JEM and JTEM exposure assessments. Exposure is often underestimated by healthcare workers in other studies, possibly because some workers do not know the components of the cleaning and disinfecting products they use. In the study by Donnay *et al*,¹ investigators observed an underestimation of self-report compared with expert exposure assessment for all hazards.

In respiratory epidemiology, few JEMs have been designed to evaluate occupational risk factors for asthma^{23,24} or chronic obstructive pulmonary disease.^{19,25} An asthma-specific JEM assessing exposure to asthmagens (known risk factors for occupational asthma), including exposure to non-specific disinfectants²³ has been widely used.^{26,27} Two JEMs have been developed in healthcare workers to estimate exposure to a large group of agents²⁸ and tasks⁶ in France and in the USA, but do not provide specific information regarding the components of cleaning or disinfecting agents.

Quantitative exposure estimates, such as exposure to volatile organic compounds (VOCs), may provide a more accurate characterisation of exposure,²⁹ but there are also limitations. First, detection limits prevent determination of precise measurements.^{30,31} Moreover, for some agents such as quats, atmospheric measurements are difficult due to the low volatility of the agent.² Finally, duration of exposure cannot be taken into account, and other sources of VOCs such as building materials can induce errors in measurement.³² Until now, only one study with measurement data in US healthcare workers is available.²⁹ In this study, personal VOC exposures varied among occupations, but different nursing jobs were not distinguished.²⁹

Interest of the JTEM

We believe that we are the first to develop a nurse-specific JTEM to evaluate occupational exposure to specific disinfectants while taking into account the variability of exposure within a given nursing job according to the disinfecting tasks performed.

In previous epidemiological studies in healthcare workers, registered nurses were considered as a single job.^{10,33} The importance to consider tasks in a job has been suggested in the literature.^{12,14,15} Taking into account tasks, Droste *et al*¹⁵ found significant associations between lung cancer and occupational exposure to carcinogens evaluated through a JTEM, but not with self-report. Our results suggest that the JTEM is more accurate than the JEM to evaluate exposures for most nursing jobs, except for ER and education/administration nursing in which exposure seems more homogeneous within the job.

Using the JTEM rather than a JEM reduces the loss of information due to the grouping of individual data.³⁴ In this study, compared with the JTEM, the JEM estimates lacked sensitivity for high exposure level, as well as specificity for medium exposure level. Both lack of specificity and lack of sensitivity lead to important bias towards the null when evaluating associations with health outcomes.³⁵ For future work, the JTEM will be applied to study the association between occupational exposure to disinfectants and asthma in the NHSII cohort.

Specific disinfectants and cleaning agents

Cleaning and disinfecting products are complex mixtures of many chemicals components that can cause or exacerbate asthma because of their irritant or sensitiser properties³ by a mechanism still not well understood. In our study, we designed the JEM and JTEM to evaluate cleaning products and disinfectants considered as irritants (eg, bleach, ammonia) and sensitisers (eg, quats, glutaraldehyde).^{36,37} Exposure estimates for each nursing job and task are consistent with the typical use of specific disinfectants in hospitals. For instance, quats are commonly used as non-critical surface (eg, floors, furniture) disinfectants as well as for disinfection of medical equipment which is in contact with the skin;³⁸ glutaraldehyde is used especially for high-level disinfecting of medical equipment such as endoscopes.³⁸ In this study, use of formaldehyde at work was mainly reported by OR nurses, and all of them were assigned the highest exposure level by the JTEM regardless of the cleaning tasks. A possible explanation is that OR nurses use formaldehyde for specific tasks such as biopsy and not for disinfecting tasks.³⁸ In addition, given the low proportion of nurses reporting using formaldehyde, we had to use a minimum cut-off value of 10% for 'high' exposure and 5% for 'medium' exposure. Since formaldehyde exposure is most likely heterogeneous, this cut-off may poorly discriminate high exposures to formaldehyde. For example, it is unlikely that OR nurses without disinfecting tasks have high-level exposure (see table 2).

Formaldehyde has been classified as a human carcinogen by the International Agency for Research on Cancer (IARC) and a probable carcinogen by the US Environmental Protection Agency (EPA). Accordingly, its use has probably decreased in hospitals as limited contact with formaldehyde has been recommended.³⁸

In a study conducted in five US hospitals, cleaning and disinfecting tasks (at least once per shift) were frequent among registered nurses (66%),⁹ consistent with our results. Among US hospital workers,⁶ self-reported exposures to cleaning and disinfecting products during instrument cleaning (42%) and building surface cleaning (78%) were higher than in this study. In a French study of hospital workers,¹ 15% reported exposure to formaldehyde, 39% to bleach, 64% to alcohol, 14% to quats, 7% to ammonia and 39% to sprays, which is higher than in this study for all disinfectants, except for quats. However, the study population included cleaners in

hospitals, who may have higher exposure levels than nurses. Interestingly, the ranking (most to least frequently used) of the disinfectants was the same as in our study. In another French study, much higher exposure levels were observed (eg, 98% of registered nurses reported occupational exposure to quats).² However, exposure was defined as reported use of products at least once a month, whereas in this study weekly exposure was considered. Weekly use of disinfectant or cleaning products has been associated with asthma, whereas few studies underline the impact of sporadic exposure (except for a high peak of exposure).

Strengths and limitations

The strengths of our study are its large sample size (n=9073) and high participation rate (91%). As shown by Delclos *et al*¹⁰ for cleaning and disinfecting products, it is helpful to construct a JEM blinded to health outcomes to avoid differential misclassification of exposure. Accordingly, we designed the JEM and JTEM using a sample of nurses without asthma to assess occupational exposure independently of the disease. Moreover, we designed the JEM and JTEM through a detailed occupational questionnaire providing specific information on cleaning or disinfecting agents, and on instrument and surface cleaning tasks, previously shown to be relevant in terms of asthma risk.⁶ We have further collected data on the brand names of the products used by the nurses, and re-evaluated individual exposures to specific chemicals using information from safety data sheets. We used a standardised method to determine product-specific cut-off for high, medium and low exposure levels. In addition, we designed the JTEM using three different methods, based on weekly exposure only or further considering exposure intensity and frequency. The method based on intensity required more assumptions (eg, that intensity was the same for all disinfectants used), and its accuracy may be further limited by the relatively low proportion of participants reporting to be exposed more than 1 hour/day. However, for all three methods used to design the JTEM, close exposure assessments were observed for most specific disinfectants (which was less the case for JEMs), supporting the validity of the JTEM estimates. Finally, using the proposed JTEM to evaluate exposure to many disinfectants among nurses is not costly as it is only based on three simple questions (type of nursing job and 2 general cleaning tasks). This tool is thus of particular interest for applications to epidemiological studies of large populations.

The JEM and JTEM we developed also have limitations. First, for some disinfectants (acetic acid, ammonia, chloramine T, ethylene oxide, ortho-phthalaldehyde, peracetic acid, phenolics), the exposure assessment was not available due to the low exposure prevalence (<10%) in all nursing jobs.³⁹ However, nurses' exposure to these chemicals is likely to be limited or passive. For example, peracetic acid is used in automated machines for instrument sterilisation. Ammonia and phenolics, sometimes used to clean environmental surfaces (eg, bedside tables, bedrails, floors),^{3, 38} may be used more often by other workers (cleaners, technicians).⁹ Furthermore, the JEM and JTEM were developed in a population of US registered nurses, and the reproducibility of these methods in other populations requires further study. Finally, we could not formally validate the JEM and JTEM estimates because of lack of a gold standard, which is a classical limitation of JEMs.⁴⁰

In conclusion, cleaning and disinfecting tasks, which involved the use of various potentially asthmogenic products, are frequent among registered nurses. Occupational exposure among nurses varied widely according to both type of nursing

job and tasks. We designed a nurse-specific JTEM that allows investigators to take into account the variability of exposure within a given job. Creating reliable tools to evaluate occupational exposure to specific agents is crucial to quantify their adverse health effects and further develop optimal strategies to prevent occupational asthma. Going forward, we plan to apply the JEM and JTEM to study the association between occupational exposure to disinfectants and asthma in the whole NHSII cohort.

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FOOTNOTES

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FIGURES AND TABLES

Figure 1 Box plot of the percentage of participants reporting weekly exposure over the 24 categories defined by job types/cleaning task groups (8 job types by 3 tasks) for each disinfectant. The distribution (minimum, quartile 1 (Q1), median, Q3 and maximum) of the 24 values is presented for each disinfectant, and was used to define product-specific cut-offs to create the job-exposure matrix and the job-task-exposure matrix. Q1 and the median were used to define cut-offs for each disinfectant. For some chemicals, Q1 or median values were very low, we defined minimum cut-offs for low and high exposure as the maximal value between Q1 and 5% (minimum cut-off for low exposure category) and the maximal value between median and 10% (minimum cut-off for high exposure category). Numbers on the right of each box plot are Q1 and median values.

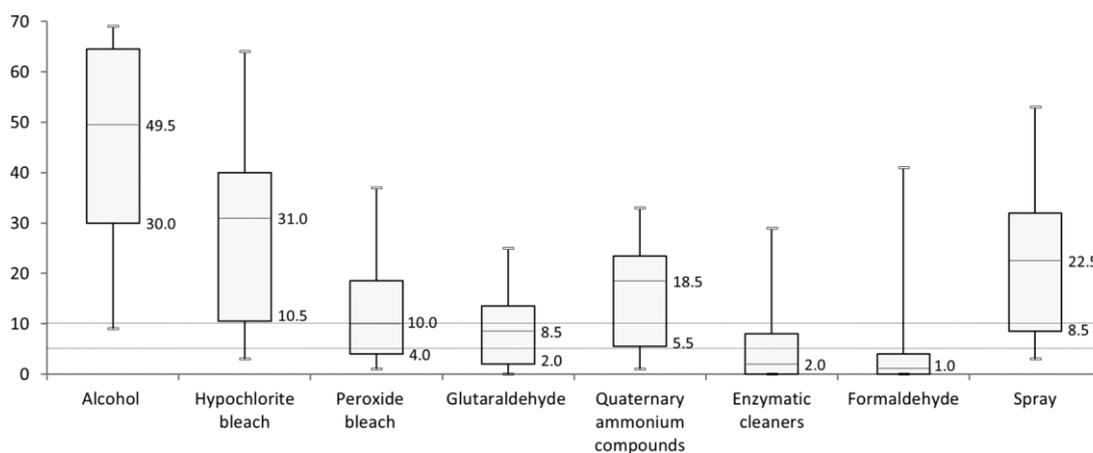


Table 1 Description of 9073 female registered nurses without asthma, drawn from the NHSII cohort

	All	Method of selection among NHSII participants	
		Random sample*	Enriched sample*
n	9073	7441	1632
Age (years), %			
49–54	22	22	25
55–59	39	38	40
60–68	39	40	35
Current job, n (%)			
ER	433 (5)	194 (3)	239 (15)
OR	1074 (12)	482 (6)	592 (36)
ICU	763 (8)	344 (5)	419 (26)
Other inpatient nurse	1158 (13)	1058 (14)	100 (6)
Outpatient or community	2086 (23)	2000 (27)	86 (5)
Other hospital nursing	904 (10)	818 (11)	86 (5)
Nursing outside hospital	1233 (13)	1195 (16)	38 (3)
Nursing in education or administration	1422 (16)	1350 (18)	72 (4)
Self-reported weekly use of disinfectants, %			
To clean surfaces	54	50	74
To clean instruments	21	19	29
Multiple exposures (number of products), self-reported, %			
0	45	48	29
1	24	24	27
2	18	17	23
≥3	13	11	21
Intensity of exposure (hour/day), self-reported, %			
<1	89	90	84
1–4	9	8	13
>4	2	2	3
Only administrative tasks, %	20	23	6

*Random sample: selected at random among all women in a nursing job in 2011. Enriched sample: selected at random among nurses in the ER, OR and ICU (more exposed to disinfectants) in 2011. ER, emergency room; ICU, intensive care unit; NHS, Nurses' Health Study; OR, operating room.

Figure 2 Reported use of disinfectants and evaluation of exposure by the job-exposure matrix (JEM) and by the job-task-exposure matrix (JTEM). Reported frequency of use of disinfectants (alcohol (n=8719), hypochlorite bleach (n=8628), peroxide bleach (n=8589), glutaraldehyde (n=8512), quaternary ammonium compounds (n=8734), enzymatic cleaners (n=8549), formaldehyde (n=8676) and spray (n=8995) and evaluation of exposure by the JEM (n=9073) and by the JTEM (n=8926). For the seven disinfectants and spray, reported frequency of use was missing for 0.9 to 6.6% of the participants.

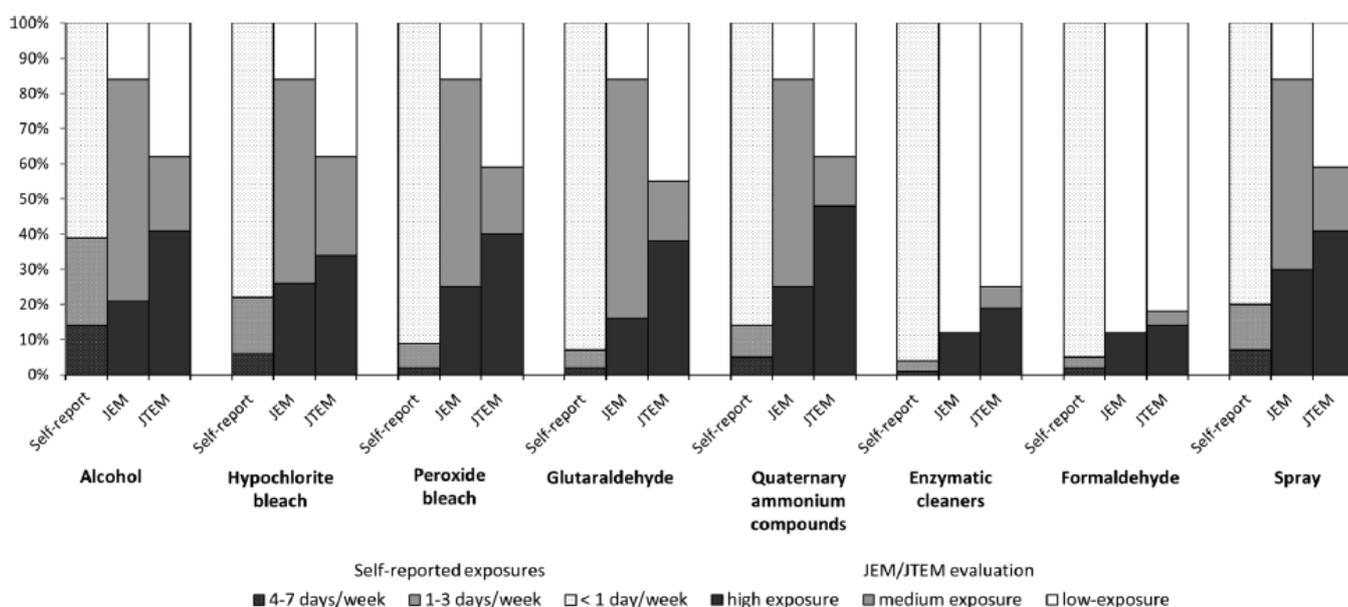


Table 2 Examples of level of exposure evaluated through job-exposure (JEM) and job-task-exposure (JTEM) matrices using percentage of self-reported weekly use of disinfectants

Jobs	Tasks	n	Hypochlorite bleach			Glutaraldehyde		Quaternary ammonium compounds		Formaldehyde	
			Per cent	Exposure level	Per cent	Exposure level	Per cent	Exposure level	Per cent	Exposure level	
Emergency room											
JEM		433	38	2	11	2	21	2	0	0	
JTEM	Clean only surfaces	287	39	2	11	2	22	2	0	0	
	Clean at least instruments*	91	56	2	18	2	33	2	1	0	
	No disinfecting tasks	49	4	0	0	0	2	0	0	0	
Operating room											
JEM		1074	24	1	11	2	20	2	30	2	
JTEM	Clean only surfaces	574	24	1	10	2	24	2	32	2	
	Clean at least instruments*	279	36	2	19	2	23	2	41	2	
	No disinfecting tasks	204	9	0	3	0	4.6	0	11	2	
Outpatient or community											
JEM		2086	18	1	8	1	14	1	2	0	
JTEM	Clean only surfaces	709	27	1	10	2	22	2	2	0	
	Clean at least instruments*	387	37	2	22	2	24	2	9	1	
	No disinfecting tasks	957	4	0	1	0	3	0	0	0	
Nursing in education or administration											
JEM		1422	10	0	1	0	4	0	0	0	
JTEM	Clean only surfaces	226	34	2	4	0	14	1	0	0	
	Clean at least instruments*	45	64	2	7	1	14	1	0	0	
	No disinfecting tasks	1128	3	0	0	0	2	0	0	0	

*Most nurses in this category reported cleaning instrument and surfaces.

Data are presented as n, percentage of self-reported weekly use and corresponding JEM/JTEM exposure level estimate.

Exposure was evaluated in three classes (0: low; 1: medium; 2: high) using product-specific cut-offs defined from the distribution of the percentage of self-reported exposure per job and tasks (see figure 1(see online supplementary table E3)).

Results are presented as n and rounded percentages (to the nearest whole number, or to the first decimal if the value was close to the JEM/JTEM cut-off).

Table 3 Comparison of job-exposure (JEM) and job-task-exposure (JTEM) matrices exposure assessments

n=9073	JEM exposure evaluation, %	JTEM exposure evaluation, %	κ coefficient	Phi coefficient	Sensitivity*	Specificity*
Exposure: high versus medium and low						
Alcohol	21	41	0.33	0.36	39	91
Hypochlorite bleach	26	34	0.31	0.31	45	84
Peroxide bleach	25	40	0.32	0.34	43	87
Glutaraldehyde	17	38	0.36	0.42	37	95
Quaternary ammonium compounds	25	48	0.36	0.40	43	92
Enzymatic cleaners	12	19	0.55	0.58	50	97
Formaldehyde	12	14	0.92	0.92	86	100
Spray	30	41	0.32	0.33	48	83
Exposure: high and medium vs low						
Alcohol	84	62	0.32	0.38	95	34
Hypochlorite bleach	84	62	0.32	0.38	95	34
Peroxide bleach	84	59	0.29	0.35	95	31
Glutaraldehyde	84	55	0.34	0.45	99	33
Quaternary ammonium compounds	84	62	0.32	0.38	95	34
Enzymatic cleaners	12	25	0.57	0.63	47	100
Formaldehyde	12	18	0.76	0.78	66	100
Spray	84	59	0.29	0.35	95	31

McNemar tests: p value <0.0001 for all disinfectant and exposure.

*Considering JTEM as reference.

ONLINE SUPPLEMENT

Development of a Job-Task-Exposure Matrix to assess occupational exposure to disinfectants among U.S. nurses

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Table E1. Design of the 3 methods to evaluate occupational exposures by JEM and JTEM, example for exposure to hypochlorite bleach among emergency room nurses

Method 1: Based on the frequency of weekly exposure		Method 2: Based on the percentage of a score, combining frequency & intensity of exposure, greater than 2		Method 3: Based on the value of a weighted score using the frequency of exposure	
JEM 1 Job axis: 8 job types*	JTEM 1 “Job-Task” axis: 8 job types* x 3 tasks†	JEM 2 Job axis: 8 job types*	JTEM 2 “Job-Task” axis: 8 job types* x 3 tasks†	JEM 3 Job axis: 8 job types*	JTEM 3 “Job-Task” axis: 8 job types* x 3 tasks†
Example 1	Example 2	Example 3	Example 4	Example 5	Example 6
38% of ER nurses reported weekly use of HB	39% of ER nurses who clean only surfaces reported weekly use of HB 56% of ER nurses who clean at least instruments reported weekly use of HB 4% of ER nurses without disinfecting tasks reported weekly use of HB	20% of ER nurses had a score ≥ 2 for HB	19% of ER nurses who clean only surface had a score ≥ 2 for HB 33% of ER nurses who clean at least instruments had a score ≥ 2 for HB 0% of ER nurses without disinfecting tasks had a score ≥ 2 for HB	ER nurses had a score of 105 for HB	ER nurses who clean only surfaces had a score of 108 for HB ER nurses who clean at least instruments had a score of 156 for HB ER nurses without disinfecting tasks had a score of 9 for HB
Cuf-offs of Hypochlorite Bleach					
- 0 (low exposure): percentage less than 11%		- 0 (low exposure): less than 5% of score ≥ 2		- 0 (low exposure): weighted score less than 24	
- 1 (medium exposure): percentage from 1% to 30.9%		- 1 (medium exposure): between 5 and 10.9 % of score ≥ 2		- 1 (medium exposure): weighted score between 24 and 81.9	
- 2 (high exposure): percentage greater or equal to 31%		- 2 (high exposure): greater or equal to 11% of score ≥ 2		- 2 (high exposure): score greater or equal to 82	
38% is greater than 31% → ER nurses classified with high exposure to HB	39% is higher than 31% → ER nurses who clean only surfaces classified with high exposure to HB 56% is higher than 31% → ER nurses who clean at least instruments classified with high exposure to HB 4% is lower than 11% → ER nurses without disinfecting tasks classified with low exposure to HB	20% is greater than 11% → ER nurses classified with high exposure to HB	19% is higher than 11% → ER nurses who clean only surfaces classified with high exposure to HB 33% is higher than 11% → ER nurses who clean at least instruments were classified with high exposure to HB 0% is lower than 5% → ER nurses without disinfecting tasks are classified low exposure to HB	105 is greater than 82 → ER nurses classified with high exposure to HB	108 is higher than 82 → ER nurses who clean only surfaces classified with high exposure to HB 156 is higher than 82 → ER nurses who clean at least instruments classified with high exposure to HB 9 is lower than 24 → ER nurses without disinfecting tasks classified with low exposure to HB

HB: hypochlorite bleach; Frequency of exposure: 0:non-weekly exposed, 1:exposed 1-3 d/wk, 2:4-7 d/wk (Q14, Figure E2); Intensity: 1:exposed <1h/d, 2:1-4h/d, 3:>4h/d (Q15, Figure E2)

* Emergency room (ER), operating room, intensive care unit, other inpatient nurse, outpatient/community, other hospital nursing, nursing outside hospital, nursing education or administration ; † use disinfectants to clean surfaces only, to clean instruments (with/without surfaces), none

The first method of exposure assessment was based on the frequency of exposure in 2 categories (0:non-weekly exposed (never or <1 day/week), 1:exposed (1-3 or 4-7 days/week)).

The second method was based on a score (ranged 0 to 6; 0:non-weekly exposed, 1:exposed 1-3 days/week(d/w) & <1 hour/day(h/d), 2:1-3 d/w & 1-4 h/d or 4-7d/w & <1h/d, 3:1-3 d/w & >4 h/d, 4:4-7 d/w & 1-4 h/d, 5:4-7 d/w & 1-4 h/d, 6:4-7 d/w & >4 h/d) combining frequency and intensity of exposure. The score was calculated for each nurse with the assumption that intensity was the same for all disinfectants used. Then, the score was classified in 3 levels: non-weekly exposed (score=0), low frequency and intensity of exposure (score=1), weekly exposed at moderate/high intensity (score ≥ 2). To design the JEM and the JTEM, the percentage of the category score ≥ 2 was used.

The third method was based on a weighted score according to the frequency of exposure to specific chemicals using the frequency weighted by 2 (1-3 d/wk) and 5 (4-7 d/wk), e.g. 2*(% exposure 1-3 d/wk) + 5*(% exposure 4-7 d/wk).

Table E2. Cut-offs for the 3 methods

	Method 1			Method 2			Method 3		
	Self-reported weekly exposures (%)			Score ≥ 2 (%)			Weighted score based on exposure frequency		
	0 : Low exposure	1 : Medium exposure	2 : High exposure	0 : Low exposure	1 : Medium exposure	2 : High exposure	0 : Low exposure	1 : Medium exposure	2 : High exposure
Alcohol	<30	30-49.9	≥ 50	<10	10-20.9	≥ 21	<83	83-146.9	≥ 147
Hypochlorite bleach	<11	11-30.9	≥ 31	<5	5-10.9	≥ 11	<24	24-81.9	≥ 82
Peroxide bleach	<5	5-9.9	≥ 10	<5	5-9.9	≥ 10	<10	10-39.9	≥ 40
Glutaraldehyde	<5	5-9.9	≥ 10	<5	5-9.9	≥ 10	<10	10-39.9	≥ 40
Quaternary ammonium compounds	<5	5-18.9	≥ 19	<5	5-9.9	≥ 10	<15	15-60.9	≥ 61
Enzymatic cleaners	<5	5-9.9	≥ 10	<5	5-9.9	≥ 10	<10	10-39.9	≥ 40
Formaldehyde	<5	5-9.9	≥ 10	<5	5-9.9	≥ 10	<10	10-39.9	≥ 40
Use spray or aerosol	<10	10-22.9	≥ 23	<5	5-9.9	≥ 10	<24	24-65.9	≥ 66

Table E3. Description of the use of disinfectants per nursing jobs

	All (n=9,021)	Use of disinfectants for instruments or surfaces			
		Never (n=2,100)	<1 day/week (n=1,773)	1-3 days/week (n=2,956)	4-7 days/week (n=2,192)
Current job, %					
Emergency room	433	5.1	6.9	56.4	31.6
Operating room	1,068	5.8	13.7	33.0	47.5
Intensive care unit	760	4.6	13.8	63.8	17.8
Other inpatient nurse	1,155	11.2	17.7	46.7	24.4
Outpatient or community	2,074	26.2	20.6	27.2	26.0
Other hospital nursing	900	20.2	20.8	30.6	28.4
Nursing outside hospital	1,222	34.0	20.4	23.5	22.2
Nursing in education or administration	1,409	50.5	30.3	14.7	4.5

Weekly use: 1-3 days/week or 4-7 days/week

Table E4. Percentage of self-reported weekly use of disinfectants and spray, used to create Job- and Job-Task -Exposure Matrix - Method 1

Jobs	Tasks	n	Alcohol		Hypochlorite bleach		Peroxide bleach		Glutaraldehyde		Quats		Enzymatic cleaners		Formaldehyde		Spray		
			%	E	%	E	%	E	%	E	%	E	%	E	%	E	%	E	
Emergency Room	JEM1	433	45.9	1	37.9	2	20.6	2	11.5	2	21.4	2	3.4	0	0.5	0	27.8	2	
	JTEM1	Clean only surfaces	287	47.5	1	38.9	2	18.7	2	11.5	2	21.6	2	1.6	0	0.4	0	23.0	2
		Clean at least instruments*	91	63.5	2	56.1	2	37.5	2	18.0	2	32.6	2	11.0	2	1.3	0	53.3	2
		No disinfecting tasks	49	10.6	0	4.4	0	4.4	0	0.0	0	2.1	0	0.0	0	0.0	0	8.2	0
Operating Room	JEM1	1,074	47.7	1	24.0	1	17.1	2	11.3	2	19.9	2	16.6	2	30.4	2	28.3	2	
	JTEM1	Clean only surfaces	574	45.8	1	23.7	1	15.8	2	10.4	2	24.1	2	14.5	2	31.9	2	28.0	2
		Clean at least instruments*	279	67.9	2	36.0	2	28.1	2	19.5	2	22.8	2	29.2	2	41.3	2	41.7	2
		No disinfecting tasks	204	25.0	0	9.1	0	5.6	1	2.6	0	4.6	0	5.2	1	11.1	2	10.3	1
Intensive Care Unit	JEM1	763	56.9	2	37.7	2	12.1	2	8.8	1	23.7	2	0.9	0	0.1	0	16.8	1	
	JTEM1	Clean only surfaces	306	56.4	2	35.3	2	9.9	1	6.6	1	28.0	2	0.4	0	0.3	0	15.8	1
		Clean at least instruments*	310	68.4	2	51.1	2	18.5	2	14.6	2	23.9	2	1.8	0	0.0	0	21.4	1
		No disinfecting tasks	134	32.6	1	14.3	1	3.8	0	2.3	0	13.4	1	0.0	0	0.0	0	8.3	0
Other Inpatient nurse	JEM1	1,158	51.0	2	31.9	2	8.5	1	7.6	1	17.1	1	3.1	0	2.3	0	18.2	1	
	JTEM1	Clean only surfaces	443	50.7	2	29.1	1	7.1	1	9.0	1	21.6	2	2.5	0	2.9	0	20.2	1
		Clean at least instruments*	367	66.3	2	53.8	2	13.7	2	11.9	2	21.3	2	6.2	1	2.9	0	25.6	2
		No disinfecting tasks	330	33.7	1	11.4	1	4.4	0	1.6	0	6.0	1	0.6	0	0.9	0	7.3	0
Outpatient or community	JEM1	2,086	42.1	1	17.8	1	8.0	1	7.7	1	13.6	1	3.9	0	2.3	0	21.5	1	
	JTEM1	Clean only surfaces	709	50.0	2	26.8	1	9.7	1	10.0	2	22.5	2	2.7	0	1.8	0	30.1	2
		Clean at least instruments*	387	67.0	2	36.6	2	20.5	2	22.5	2	24.5	2	15.2	2	8.8	1	36.4	2
		No disinfecting tasks	957	26.6	0	4.1	0	1.6	0	0.6	0	2.8	0	0.3	0	0.2	0	8.8	0
Other hospital nursing	JEM1	904	33.6	1	21.0	1	8.8	1	9.1	1	14.0	1	3.9	0	4.2	0	16.6	1	
	JTEM1	Clean only surfaces	359	39.5	1	23.4	1	10.4	2	9.3	1	20.2	2	4.2	0	4.7	0	21.7	1
		Clean at least instruments*	165	66.9	2	48.1	2	21.6	2	25.2	2	25.8	2	11.6	2	10.7	2	31.5	2
		No disinfecting tasks	365	13.5	0	7.0	0	1.9	0	2.2	0	2.5	0	0.3	0	0.8	0	4.7	0
Nursing outside hospital	JEM1	1,233	36.1	1	18.9	1	7.8	1	6.1	1	8.1	1	2.0	0	0.8	0	24.4	2	
	JTEM1	Clean only surfaces	351	50.0	2	33.0	2	11.5	2	7.9	1	16.9	1	1.5	0	0.6	0	44.0	2
		Clean at least instruments*	202	68.7	2	41.1	2	20.0	2	21.1	2	16.7	1	10.0	2	3.1	0	48.3	2
		No disinfecting tasks	658	18.9	0	4.8	0	2.3	0	0.5	0	1.1	0	0.0	0	0.2	0	6.4	0
Nursing in education or administration	JEM1	1,422	16.5	0	10.0	0	3.2	0	1.4	0	4.0	0	0.5	0	0.2	0	7.9	0	
	JTEM1	Clean only surfaces	226	48.4	1	34.4	2	13.3	2	4.2	0	14.2	1	2.3	0	0.5	0	25.0	2
		Clean at least instruments*	45	59.1	2	63.6	2	9.3	1	7.1	1	13.9	1	2.3	0	0.0	0	33.3	2
		No disinfecting tasks	1,128	8.6	0	3.1	0	0.8	0	0.5	0	1.7	0	0.1	0	0.2	0	3.5	0

Results are presented, for each disinfectant, as % of self-reported weekly use, and corresponding JEM / JTEM exposure level estimate. Exposure was evaluated in 3 classes (0: low; 1: medium; 2: high) using product-specific cut-offs defined from the distribution of the percentage of self-reported exposure per job and tasks.

*Most nurses in this category reported cleaning instrument and surfaces. Results presented as percentages, unless otherwise specified. Quats: Quaternary ammonium compounds

Table E5. Comparison of JEM and JTEM exposure assessments by hospital units - Method 1

		n	Alcohol	Hypochlorite bleach	Peroxide bleach	Glutaraldehyde	Quats	Enzymatic cleaners	Formaldehyde	Spray
Emergency Room	JEM 1	427	Medium	High	High	High	High	Low	Low	High
	JTEM1		12	11	11	11	11	79	100	11
	Low, %		67	0	0	0	0	0	0	0
	Medium, %		21	89	89	89	89	21	0	89
High, %										
Operating Room	JEM 1	1,057	Medium	Medium	High	High	High	High	High	High
	JTEM1		19	19	0	0	0	0	0	0
	Low, %		54	54	19	19	19	19	0	19
	Medium, %		27	27	81	81	81	81	100	81
High, %										
Intensive Care Unit	JEM 1	750	High	High	High	Medium	High	Low	Low	Medium
	JTEM1		0	0	18	18	0	100	100	18
	Low, %		18	18	41	41	18	0	0	82
	Medium, %		82	82	41	41	82	0	0	0
High, %										
Other Inpatient nurse	JEM 1	1,140	High	High	Medium	Medium	Medium	Low	Low	Medium
	JTEM1		0	0	29	29	0	68	100	29
	Low, %		29	68	39	39	29	32	0	39
	Medium, %		71	32	32	32	71	0	0	32
High, %										
Outpatient or community	JEM 1	2,053	Medium	Medium	Medium	Medium	Medium	Low	Low	Medium
	JTEM1		47	47	47	47	47	81	81	47
	Low, %		0	34	34	0	0	0	19	0
	Medium, %		53	19	19	53	53	19	0	53
High, %										
Other hospital nursing	JEM 1	889	Medium	Medium	Medium	Medium	Medium	Low	Low	Medium
	JTEM1		41	41	41	41	41	81	81	41
	Low, %		40	40	0	40	0	0	0	40
	Medium, %		19	19	59	19	59	19	19	19
High, %										
Nursing outside hospital	JEM 1	1,211	Medium	Medium	Medium	Medium	Medium	Low	Low	High
	JTEM1		54	54	54	54	54	83	100	54
	Low, %		0	0	0	29	46	0	0	0
	Medium, %		46	46	46	17	0	17	0	46
High, %										
Nursing in education or administration	JEM 1	1,399	Low	Low	Low	Low	Low	Low	Low	Low
	JTEM1		81	81	81	97	81	100	100	81
	Low, %		16	0	3	3	19	0	0	0
	Medium, %		3	19	16	0	0	0	0	19
High, %										

0: low exposure; **1:** medium; **2:** high; Quats: Quaternary ammonium compounds

Table E6. Comparison of the three methods to evaluate JEM and JTEM exposure

			Alcohol	Hypochl. Bleach	Peroxyde Bleach	Glutaraldehyde	Quats	Enzyme cleaners	Formaldehyde	Sprays
Emergency Room	JTEM 1/2/3	JEM 1/2/3	1/2/1	2/2/2	2/1/2	2/1/1	2/2/2	0/0/0	0/0/0	2/2/2
		Clean only surfaces	1/2/1	2/2/2	2/1/2	2/1/1	2/2/2	0/0/0	0/0/0	2/2/1
		Clean at least instruments *	2/2/2	2/2/2	2/2/2	2/2/2	2/2/2	2/1/1	0/0/0	2/2/2
		No disinfecting tasks	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0
Operating Room	JTEM 1/2/3	JEM 1/2/3	1/2/2	1/2/1	2/1/2	2/1/1	2/2/2	2/1/2	2/2/2	2/2/2
		Clean only surfaces	1/2/2	1/2/1	2/1/2	2/1/1	2/2/2	2/1/2	2/2/2	2/2/2
		Clean at least instruments *	2/2/2	2/2/2	2/2/2	2/2/2	2/2/2	2/2/2	2/2/2	2/2/2
		No disinfecting tasks	0/0/0	0/0/0	1/0/1	0/0/0	0/0/0	1/0/1	2/0/1	1/0/1
Intensive Care Unit	JTEM 1/2/3	JEM 1/2/3	2/1/2	2/1/2	2/0/1	1/0/1	2/1/2	0/0/0	0/0/0	1/1/1
		Clean only surfaces	2/1/2	2/1/2	1/0/1	1/0/1	2/1/2	0/0/0	0/0/0	1/0/1
		Clean at least instruments *	2/2/2	2/2/2	2/1/2	2/1/1	2/1/2	0/0/0	0/0/0	1/1/1
		No disinfecting tasks	1/0/1	1/0/1	0/0/0	0/0/0	1/0/1	0/0/0	0/0/0	0/0/0
Other Inpatient nurse	JTEM 1/2/3	JEM 1/2/3	2/1/2	2/1/2	1/0/1	1/0/1	1/1/1	0/0/0	0/0/0	1/1/1
		Clean only surfaces	2/1/1	1/1/1	1/0/1	1/0/1	2/1/2	0/0/0	0/0/0	1/1/1
		Clean at least instruments *	2/2/2	2/2/2	2/0/1	2/0/1	2/1/2	1/0/1	0/0/0	2/2/2
		No disinfecting tasks	1/1/1	1/0/1	0/0/0	0/0/0	1/0/1	0/0/0	0/0/0	0/0/0
Outpatient or community	JTEM 1/2/3	JEM 1/2/3	1/2/1	1/1/1	1/0/1	1/0/1	1/1/1	0/0/1	0/0/0	1/1/1
		Clean only surfaces	2/2/2	1/1/1	1/0/1	2/0/1	2/2/2	0/0/0	0/0/0	2/2/2
		Clean at least instruments *	2/2/2	2/2/2	2/2/2	2/2/2	2/2/2	2/1/2	1/1/1	2/2/2
		No disinfecting tasks	0/1/0	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0	0/0/1
Other hospital nursing	JTEM 1/2/3	JEM 1/2/3	1/1/1	1/1/1	1/0/1	1/1/1	1/1/1	0/0/1	0/0/1	1/1/1
		Clean only surfaces	1/1/1	1/2/1	2/1/1	1/0/1	2/2/2	0/0/1	0/0/1	1/2/2
		Clean at least instruments *	2/2/2	2/2/2	2/1/2	2/2/2	2/2/2	2/2/2	2/2/1	2/2/2
		No disinfecting tasks	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0
Nursing outside hospital	JTEM 1/2/3	JEM 1/2/3	1/1/1	1/1/1	1/0/1	1/0/1	1/0/1	0/0/0	0/0/0	2/2/2
		Clean only surfaces	2/2/2	2/2/2	2/0/1	1/0/1	1/1/1	0/0/0	0/0/0	2/2/2
		Clean at least instruments *	2/2/2	2/2/2	2/1/2	2/2/2	1/2/1	2/1/1	0/0/0	2/2/2
		No disinfecting tasks	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0
Nursing in education or administration	JTEM 1/2/3	JEM 1/2/3	0/0/0	0/0/1	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0
		Clean only surfaces	1/1/1	2/1/2	2/0/1	0/0/0	1/1/1	0/0/0	0/0/0	2/1/2
		Clean at least instruments *	2/2/2	2/2/2	1/0/1	1/0/1	1/1/1	0/0/0	0/0/0	2/2/2
		No clean	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0

Method 1 (JEM 1 and JTEM 1) was defined by taking into account the percentage of participants reporting weekly exposure;

Method 2 (JEM 2 and JTEM 2) was defined from a score combining frequency & intensity of exposure;

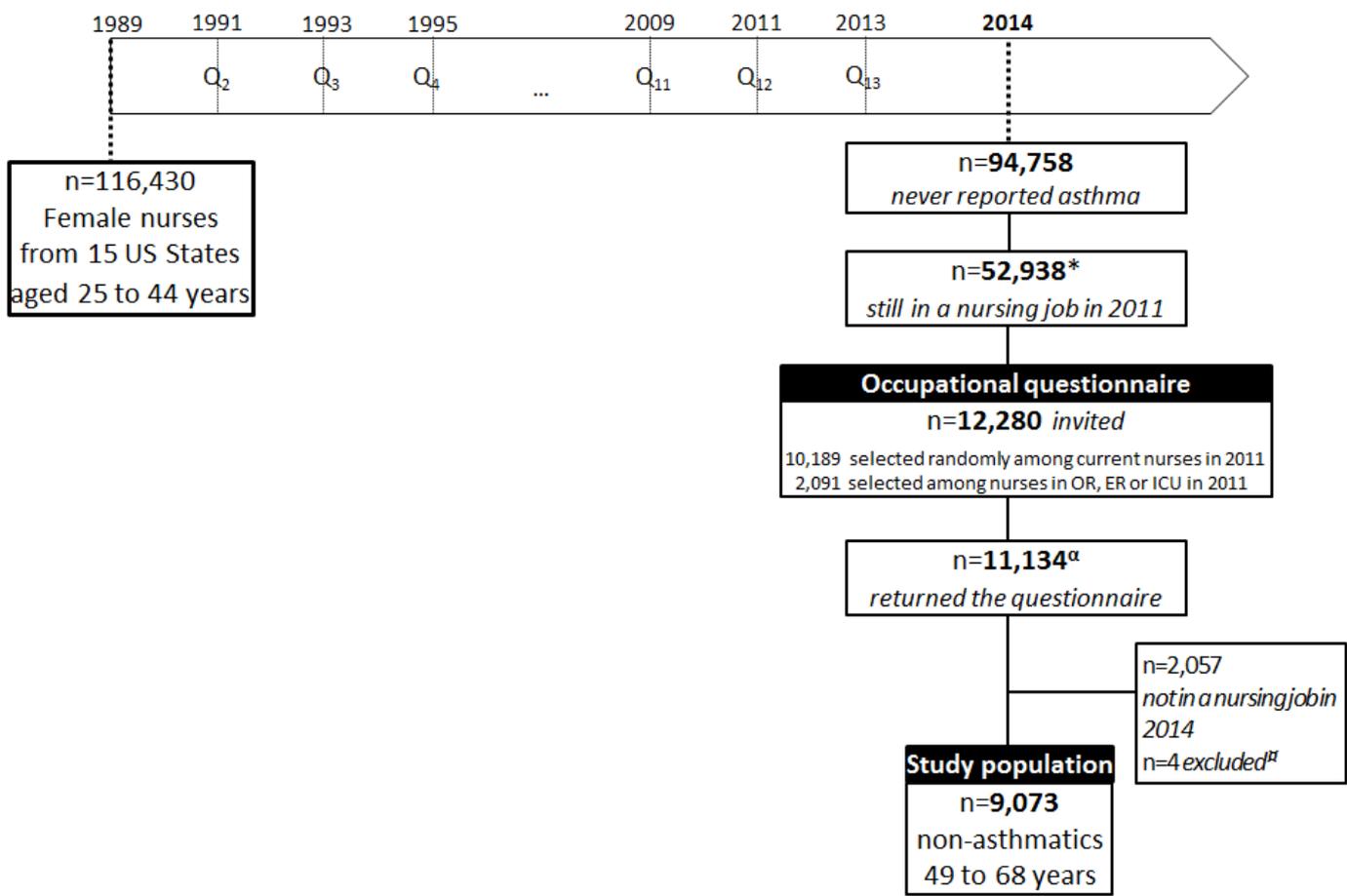
Method 3 (JEM 3 and JTEM 3) was defined from weighted score using the reported exposure frequency (see Tables E1 and E3 for more details)

(0: low exposure; 1: medium; 2: high)

Table E7. Comparison of self-report, JEM and JTEM exposure assessment according to age - Method 1

n=9,073 Days/weeks	Self-report %		JEM1 exposure evaluation %		JTEM1 exposure evaluation %	
	1-3 days/week	4-7 days/week	medium	high	medium	high
49-54 years (n=2,045)						
Alcohol	25	15	61	24	22	46
Hypochlorite Bleach	19	6	55	29	28	40
Peroxide Bleach	7	3	57	28	19	45
Glutaraldehyde	6	2	68	17	17	43
Quaternary ammonium compounds	10	7	57	28	15	53
Enzymatic cleaners	3	2	0	11	7	21
Formaldehyde	2	3	0	11	5	14
Spray	13	6	56	28	19	45
55-59 years (n=3,517)						
Alcohol	24	16	64	21	21	43
Hypochlorite Bleach	15	7	60	25	29	35
Peroxide Bleach	7	3	59	26	21	41
Glutaraldehyde	5	2	67	18	17	40
Quaternary ammonium compounds	8	5	59	26	15	50
Enzymatic cleaners	3	1	0	13	7	20
Formaldehyde	3	3	0	13	5	15
Spray	12	7	53	32	18	44
≥ 60 years (n=3,511)						
Alcohol	26	13	64	20	21	36
Hypochlorite Bleach	15	5	59	24	28	29
Peroxide Bleach	7	2	61	22	18	36
Glutaraldehyde	5	2	68	15	17	33
Quaternary ammonium compounds	8	4	61	22	14	43
Enzymatic cleaners	3	1	0	11	6	17
Formaldehyde	3	2	0	11	4	12
Spray	14	6	54	30	17	37

Figure E1. Flow-Chart (n=9,073)



* About 73% of them were eligible to receive a supplemental questionnaire. Eligibility was defined by having returned the 2013 biennial questionnaire at the time the supplemental questionnaire invites were sent, and not being already enrolled in another sub-study. Eligible nurses and non-eligible nurses were similar regarding the use of disinfectants in 2011.

^a 91% had returned a questionnaire (9,248 for the random sample, 1,886 for the enriched sample). Enriched sample: selected at random among nurses in ER, OR and ICU (more exposed to disinfectants) in 2011.

^α Decline sharing of data for this project

ER: emergency room nurse; OR: operating room nurses; ICU: intensive care unit nurses

Figure E2. Extract of the questionnaire

1. Which best describes your **current** employment status? ER OR ICU Other inpatient nurse Nursing education or admin
 Outpatient or community Other hospital nursing Nursing outside hospital
 Non-nursing employment F/T homemaker Disabled Retired Other

If you reported **non-nursing employment, fulltime homemaker, disabled, retired, or other**, what year did you finish your **last nursing job**? →

Thinking about your **current job** and the use of **disinfectants** (such as ethylene oxide, hydrogen peroxide, ortho-phthalaldehyde, formaldehyde, glutaraldehyde, bleach):

4. On how many **days per week**, on average, do you clean **medical instruments** with disinfectants?
 Never <1 day/week 1-3 days/week 4-7 days/week
-
5. On how many **days per week**, on average, do you clean **surfaces** (like floors, tables) at work with disinfectants?
 Never <1 day/week 1-3 days/week 4-7 days/week

14. On how many days per week do you use the following disinfectants at work?	Number of days per week			
	Never	<1 day per week	1-3 days per week	4-7 days per week
a) Formaldehyde	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
b) Glutaraldehyde (e.g., Cidex, Metricide, Rapicide, Wavicide, Aldahol III)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
c) Ortho-phthalaldehyde (e.g., Cidex OPA, Metricide OPA Plus, Opaciden)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
d) Hypochlorite bleach, chlorine (e.g., Clorox)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
e) Peroxide bleach, hydrogen peroxide (e.g., Accell, Optim, Resert XL, Sporox, Acecide, EndoSpor Plus, Peract, Sterad)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
f) Peracetic acid (e.g., Steris)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
g) Acetic acid	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
h) Alcohol [ethanol, methanol, isopropanol]	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
i) Ammonia	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
j) Quaternary ammonium compounds, "Quats" (e.g. 3M Neutral Quat 23, 3M HB Quat 25, Oasis Multi-Quat, Staphene, BTC100, BioQuat, Sentinel, Virex)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
k) Ethylene oxide (e.g., in compressed-gas cylinders, single-dose cartridges or glass ampules)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
l) Chloramine T	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
m) Phenolics (e.g., 3M Phenolic Disinfectant 18, WexCide, MicroBakII, Megacide, Novigard, Expose II 256)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
n) Enzymatic cleaners (e.g., Asepti-Zyme, 3M Rapid Multi-Enzyme)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
o) 'Green' products	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
If you don't know the active compound: p) Fill in the brand name below				
<input type="text"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
<input type="text"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
q) Other products; don't know the name	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

15. On days with **disinfectant use**, how many **hours**, on average, do you use disinfectants?
 Less than 1 hour a day 1-4 hours per day More than 4 hours a day