Evaluation of exposure to a hydrogen peroxide, peracetic acid, and acetic acid containing cleaning and disinfection product and symptoms in hospital employees

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Contents

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The cover photo is a close-up image of sorbent tubes, which are used by the HHE Program to measure airborne exposures. This photo is an artistic representation that may not be related to this Health Hazard Evaluation.

Highlights of this Evaluation

The Health Hazard Evaluation Program received a confidential employee request for the National Institute for Occupational Safety and Health to conduct a health hazard evaluation at a hospital. The request cited concerns about exposure of hospital employees to OxyCide®, a disinfectant cleaner that is one of a group of sporicidal products marketed under various trade names that contain hydrogen peroxide, peracetic acid, and acetic acid, and described symptoms experienced by employees. Employee symptoms noted in the health hazard evaluation request included respiratory distress, skin problems, headaches, chest tightness, burning eyes, sore throat, and nausea.

What We Did

- We visited the hospital in August 2017 to observe environmental services staff while they conducted cleaning tasks throughout the hospital and informally speak with hospital staff (environmental services, nursing, and ancillary staff) about their use of cleaning products and any related health concerns.
- We collected 14 bulk samples of the diluted sporicidal product in August 2017 to measure pH.
- In September 2017, we provided a report with our interim findings and recommendations.
- We returned in July–August 2018 to perform an air sampling survey and a health questionnaire survey. We collected full-shift time-weighted average air samples on environmental services employees and analyzed the samples for the three chemicals found in the sporicidal product: hydrogen peroxide, peracetic acid, and acetic acid. We also collected full-shift area time-weighted average air samples in multiple areas of the hospital and analyzed the samples for hydrogen peroxide, peracetic acid, and acetic acid content.
- We administered a post-shift survey with health and work questions to 55 environmental

We evaluated employee health concerns and exposures to the three main chemicals, hydrogen peroxide, peracetic acid, and acetic acid, found in a sporicidal product used by hospital cleaning staff. Hydrogen peroxide and peracetic acid were detected in all personal full-shift air samples. Some employees exposed to vapors from the sporicidal product reported work-related upper airway, eye, lower airway, and skin symptoms. We recommend management tailor use of sporicidal products containing hydrogen peroxide, peracetic acid, and acetic acid to areas of high risk for healthcare-acquired infections and minimize the use of sporicidal products on noncritical surfaces and in non-patient areas. We also recommend management provide workplace accommodations for employees who develop symptoms related to the use of products containing hydrogen peroxide, peracetic acid, and acetic acid. Additionally, we recommend several ways to reduce employee exposure to the hydrogen peroxide, peracetic acid, and acetic acid vapors and liquids from the sporicidal product.

services staff and 22 patient care and ancillary staff who worked in areas of the hospital where air samples were collected, for a total of 77 hospital employees.

- We also collected 28 bulk samples of the diluted sporicidal product from containers of diluted product located on EVS employee carts during July–August 2018 to measure peracetic acid and hydrogen peroxide concentrations.
- In September 2018, we provided a report with our interim findings and recommendations.

What We Found

- We found the sporicidal product containing hydrogen peroxide, peracetic acid, and acetic acid is used predominantly by environmental services staff and that patient-care and ancillary staff predominantly use quaternary ammonium (PDI®) or bleach wipes for routine point-of-care cleaning activities.
- We observed environmental services employees using the sporicidal product containing hydrogen peroxide, peracetic acid, and acetic acid on surfaces throughout the hospital, including patient rooms, patient bathrooms, and public bathrooms. Environmental services staff were observed using, or reported occasionally using, other products containing substances capable of causing or worsening eye and respiratory symptoms, including products containing ethanolamines, bleach, phosphoric acid, sodium xylenesulfonate, or quaternary ammonium compounds.
- We observed pH measurements of the diluted sporicidal product that ranged from 3.1–7.5. The product's safety data sheet indicates the product should be diluted to a pH of 2.7–4.0. The highest pH (7.5) was measured in a sample collected from a dispenser that indicated the concentrated product was low and needed replacement. The low level of remaining concentrated product in the dispenser could have contributed to the near-neutral pH observed.
- Concentrations of peracetic acid and hydrogen peroxide measured in samples of the diluted product varied among cart samples and ranged from 900 parts per million (ppm) to 2100 ppm for peracetic acid and 3600 ppm to 7000 ppm for hydrogen peroxide.
- For the three carts that NIOSH staff collected multiple samples from throughout the shift, peracetic acid concentrations were consistent throughout the shift and varied from 1500 ppm to 1800 ppm (3 North cart); 1200 ppm to 1500 ppm (black cart); and 1500 ppm to 2100 ppm (3 South cart). Hydrogen peroxide concentrations were also consistent throughout the shift and ranged from 4800 ppm to 6000 ppm (3 North cart); 3600 ppm to 4800 ppm (black cart); and 6000 ppm to 7000 ppm (3 South cart).
- We found that some employees using the sporicidal product containing hydrogen peroxide, peracetic acid, and acetic acid reported eye, upper respiratory, lower respiratory, and skin symptoms that began during their shift.
- We detected hydrogen peroxide and peracetic acid in all personal full-shift air samples collected on environmental services staff.

- We found that increased exposure to hydrogen peroxide, peracetic acid, or acetic acid vapors was associated with increases in acute, cross-shift work-related nasal irritation, eye irritation, shortness of breath, and wheeze symptoms reported by hospital staff, after adjusting for age, gender, smoking status, allergic status, other sensitizer or irritant containing cleaning products used during their shift, and stress.
- We also determined that increased departmental average exposure to hydrogen peroxide, peracetic acid, or acetic acid vapors was associated with increases in work-related symptoms in the previous four weeks including nasal irritation, sneeze, and eye irritation, after adjusting for age, gender, smoking status, allergic status, frequency of use of other sensitizer or irritant containing cleaning products in the previous 4 weeks, and stress.

What the Employer Can Do

- Minimize the use of sporicidal products containing hydrogen peroxide, acetic acid, and peracetic acid in non-patient care areas.
- Ensure employees understand potential hazards in the workplace and how to protect themselves. Specifically, employees should be educated on the documented health risks from exposure to hydrogen peroxide, peracetic acid, and acetic acid and chemicals found in other cleaning products at the hospital.
- Ensure the sporicidal product dispensers are calibrated to effectively dilute the product to a pH of 2.7–4.0. If the sporicidal product is not effectively diluted, a pH of less than 2.7 can increase skin, eye, and respiratory symptoms in exposed employees.
- Continue to ensure employees use only rags and wipes to apply the sporicidal product to surfaces and the sporicidal product is not used as a spray.
- Require employees to wear extended cuff nitrile gloves or rubber gloves when using the sporicidal product and goggles or a face shield while dispensing and pouring the sporicidal product into or out of the bucket on their cleaning cart.
- Consider implementing a comprehensive system for reporting and tracking workplace injuries and illnesses that includes reports of near-misses, minor injuries and illnesses, and employee safety concerns. This information should be reviewed by the Safety Officer on a regular basis to identify hazards, implement risk-reduction strategies, and prevent significant injuries and illnesses.
- Provide workplace accommodations to employees who develop work-related symptoms after exposure to sporicidal products containing hydrogen peroxide, peracetic acid, and acetic acid. Consider relocating employees who develop work-related symptoms to areas of the hospital where sporicidal products containing hydrogen peroxide, peracetic acid, and acetic acid are used less frequently.

What Employees Can Do

- Wear extended cuff nitrile gloves or rubber gloves when using the sporicidal product containing hydrogen peroxide, peracetic acid, and acetic acid. Wear goggles or a face shield when dispensing and pouring the sporicidal product into or out of the bucket on your cleaning cart.
- Keep the lid on the sporicidal product bucket closed whenever possible to minimize the generation of hydrogen peroxide, peracetic acid, and acetic acid vapors that can be inhaled.
- Report new, persistent, or worsening symptoms to your personal healthcare provider and, as instructed by your employer, to a designated individual at your workplace.

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Abbreviations

AA	Acetic acid
ACGIH®	American Conference of Governmental Industrial Hygienists
CFR	Code of Federal Regulations
COPD	Chronic obstructive pulmonary disease
CI	Confidence interval
EPA	U.S. Environmental Protection Agency
EVS	Environmental Services
°F	Degrees Fahrenheit
GM	Geometric mean
GSD	Geometric standard deviation
HICPAC	Healthcare Infection Control Practices Advisory Committee
HP	Hydrogen peroxide
HVAC	Heating, ventilation, and air-conditioning
ICU	Intensive care unit
LOD	Limit of detection
mL/min	Milliliters per minute
MVUE	Minimum-variance unbiased estimator
NIOSH	National Institute for Occupational Safety and Health
OM	Oxidant exposure mixture
OR	Odds Ratio
OSHA	Occupational Safety and Health Administration
PAA	Peracetic acid
PEL	Permissible exposure limit
PPE	Personal protective equipment
ppm	Parts per million
ppb	Parts per billion
REL	Recommended exposure limit
SD	Standard deviation
SDU	Step-down unit
STEL	Short-term exposure limit
TM	Total exposure mixture
TWA	Time-weighted average
TLV®	Threshold limit value

Summary

The National Institute for Occupational Safety and Health received a confidential employee request to conduct a health hazard evaluation at a hospital. The request cited concerns about exposure of hospital employees to a sporicidal cleaning and disinfection product containing hydrogen peroxide, peracetic acid, and acetic acid, and listed symptoms experienced by employees, including respiratory distress, skin problems, headaches, chest tightness, burning eyes, sore throat, and nausea. We performed a walk-through assessment of cleaning products used at the hospital on August 15, 2017, and informally interviewed hospital employees about cleaning products they used and any related health concerns. We observed the sporicidal product containing hydrogen peroxide, peracetic acid, and acetic acid was the main cleaning product used by environmental services staff for surface cleaning tasks.

We returned on July 31 and August 1, 2018, to perform air-sampling and administer a post-shift health questionnaire. We collected 56 full-shift air samples for hydrogen peroxide, peracetic acid, and acetic acid on or near environmental services staff performing cleaning activities. We also collected full-shift area samples in locations throughout the hospital. We observed environmental services staff while they performed their regular cleaning duties and noted task duration, cleaning product use and duration, and use of any personal protective equipment. Environmental services staff were observed occasionally using, or reported occasionally using, other sensitizer or irritant containing products including products containing quaternary ammonium compounds, bleach, phosphoric acid, sodium xylenesulfonate, or ethanolamines when cleaning general surfaces or bathroom surfaces. We also administered a voluntary post-shift health and work history questionnaire to patient-care and ancillary staff recruited from the same areas and departments of the hospital where area air samples were collected.

All full-shift time-weighted average air samples for hydrogen peroxide and acetic acid were below established U.S. occupational exposure limits. Nasal, throat, and eye irritation, as well as shortness of breath were the most frequently reported work-related symptoms in the post-shift survey of acute, cross-shift work-related symptoms. Similarly, nasal, throat, and eye irritation, as well as sneeze were the most frequently reported work-related symptoms in the post-shift survey of symptoms occurring in the previous four weeks.

We observed statistically significant positive associations between work-related acute, cross-shift eye, upper airway, and lower airway symptoms in relation to exposure to hydrogen peroxide, peracetic acid, and acetic acid vapors after adjusting for age, gender, smoking status, use of other cleaning products containing sensitizers and irritants, allergic status, and stress. Work-related acute nasal and eye irritation, and shortness of breath were significantly associated with increased exposure to hydrogen peroxide, peracetic acid, and acetic acid, indicating an increase in symptoms with increasing exposure to the mixture of vapors from the sporicidal product. Work-related acute, cross-shift wheeze was significantly associated with increases in exposure to hydrogen peroxide, one of the constituents in the sporicidal product.

We also observed positive associations between work-related eye and upper airway symptoms in the previous four weeks in relation to exposure to hydrogen peroxide, peracetic acid, and acetic acid vapors after adjusting for age, gender, smoking status, frequency of use of other cleaning products containing sensitizers and irritants, allergic status, and stress. Work-related nasal and eye irritation in the previous four weeks were significantly associated with increases in departmental concentrations to hydrogen peroxide, peracetic acid, and acetic acid. Work-related sneeze in the previous four weeks was significantly associated with increases in departmental concentrations of peracetic acid.

We identify several ways to reduce employee exposure to the sporicidal product containing hydrogen peroxide, peracetic acid, and acetic acid. We recommend that management restrict the use of sporicidal products containing hydrogen peroxide, peracetic acid, and acetic acid to areas of high risk for healthcare-acquired infections and minimize the use of sporicidal products containing hydrogen peroxide, peracetic acid, and acetic acid on non-critical surfaces and in non-patient areas. We also recommend that management provide workplace accommodations for employees who develop symptoms related to the use of sporicidal and high-level disinfectants. Management should also ensure that all heating, ventilation, and air-conditioning systems are functioning well and meet all applicable American Society of Heating, Refrigeration, and Air Conditioning Engineers standards.

Introduction

The National Institute for Occupational Safety and Health (NIOSH) received a confidential employee request to conduct a health hazard evaluation at a hospital. The request cited concerns about exposure of hospital employees to a disinfectant cleaner that is one of a group of sporicidal products that contain hydrogen peroxide (HP), peracetic acid (PAA), and acetic acid (AA) and marketed under various trade names. In their health hazard evaluation request they described symptoms experienced by employees including respiratory distress, skin problems, headaches, chest tightness, burning eyes, sore throat, and nausea.

In response to the health hazard evaluation request, we performed a walkthrough assessment of cleaning product use at the hospital on August 15, 2017, and informally interviewed employees about their cleaning product use and any related health concerns. We observed the sporicidal product containing HP, PAA, and AA was the main cleaning product used for all surface cleaning duties and was used predominantly by Environmental Services (EVS) staff. We researched similar products manufactured under different trade names and observed that cleaning and disinfecting products containing a mixture of HP, PAA, and AA are currently widely used as surface cleaners and sterilants in healthcare settings. Products containing HP, PAA, and AA intended for use as surface cleaners are typically more dilute than HP, PAA, and AA products intended for use as sterilants. The sporicidal product containing HP, PAA, and AA used at the hospital and subject of this report was diluted with water before use to a pH of 2.7─4.0.

During July 31–August 2, 2018, we returned to the hospital to perform a full-shift air sampling survey and collect air samples on employees performing cleaning activities and in areas throughout the hospital. We observed EVS staff while they performed their regular cleaning duties and noted task duration, cleaning product use and duration, and use of any personal protective equipment (PPE). We also noted that EVS staff occasionally used other products containing substances capable of causing or worsening respiratory symptoms, to include products containing ethanolamines, bleach, phosphoric acid, sodium xylenesulfonate, or quaternary ammonium compounds when cleaning floors or bathroom surfaces.

We administered a voluntary post-shift survey concerning health and cleaning product use to hospital employees during July 31–August 2, 2018. We offered the post-shift survey to all EVS staff who participated in the air sampling survey. We also offered the post-shift survey to non-EVS staff working in departments where air samples were collected.

In this report, we summarize the results from our exposure assessment. We also summarize results from the health and work history questionnaire and post-shift survey of acute symptoms. Additionally, we provide recommendations to help protect the health of employees. We previously mailed letters with interim results and recommendations in September of 2017 and September of 2018.

Process Description

The hospital that is the subject of this health hazard evaluation is a multispecialty hospital offering cardiology, intensive care unit (ICU), labor and delivery, neonatal intensive care unit, pediatric ICU, pediatrics, and surgical services. Beginning in 2015, the sporicidal product containing HP, PAA and AA became the primary disinfectant used for surface cleaning duties throughout the hospital. EVS staff were the primary housekeeping staff and performed cleaning duties and tasks in areas throughout the hospital. Other healthcare personnel, such as patient care and ancillary staff, performed occasional surface cleaning tasks, such as wiping down equipment in occupied patient rooms, as part of routine point-of-care cleaning activities. The product containing HP, PAA, and AA was used predominantly by EVS staff, and patient care and ancillary staff predominantly used PDI® or bleach wipes for routine cleaning activities.

Methods

August 2017 Bulk Sample Analysis

During the walkthrough assessment in August 2017, we collected bulk samples of the diluted sporicidal product containing HP, PAA, and AA from multiple hospital departments. Bulk samples of the diluted sporicidal product were collected to assess the sporicidal product dispenser calibration. Dispenser calibration was assessed by measuring diluted product pH at a time point less than 12 hours after collection. Samples were kept capped and stored at room temperature (21°C−23°C). Measurements of sample pH were taken using a pH meter (Fisher Scientific International Inc., Hampton, NH).

July–August 2018 Bulk Sample Analysis

We collected bulk samples of the diluted sporicidal product containing HP, PAA, and AA from multiple hospital departments. We assessed product variability by collecting bulk samples from the product bucket located on EVS employee carts and measuring the peracetic acid and hydrogen peroxide concentrations in each sample. Samples were analyzed within three hours of collection using a peracetic acid test kit (LaMotte Company, Chestertown, MD) and a hydrogen peroxide test kit (CHEMetrics Inc., Midland, VA).

July–August 2018 Air Sampling Survey

During July and August 2018, we performed an air sampling survey and collected a total of 56 full-shift time-weighted average (TWA) samples on day, evening, and night shift EVS employees. Twenty-nine of the full-shift samples were collected from employees' breathing zones while they performed their regular cleaning duties. Twenty-seven of the samples collected were mobile samples. For the mobile samples, we followed employees while they performed their cleaning duties and placed the samplers near EVS staff in the rooms while they cleaned or on their carts while they were cleaning. Additionally, we observed staff while they performed their regular cleaning duties and noted task duration, cleaning product use and duration, and use of any PPE. We also collected 70 full-shift TWA area samples for AA and 28 full-shift area samples for HP and PAA from multiple locations including the

Emergency Department, 2nd floor ICU, 2nd floor ICU Pre-Op, 3rd floor Anesthesia Admin, 3rd floor Labor and Delivery, 4th floor Pediatrics, 5th floor SDU, 6th floor Medical Surgical, 7th floor Medical Surgical, Diagnostic Imaging, and Pharmacy.

All air samples were analyzed for the three chemicals found in the sporicidal product: HP, PAA, and AA. HP and PAA were collected and analyzed according to the methods specified by Hecht et al. [2004]. AA was collected and analyzed according to the Occupational Safety and Health Administration (OSHA) Method PV2119 [OSHA 2003].

Post-Shift Survey of Health and Cleaning Product Use

We administered a voluntary post-shift survey of health and cleaning product use to 77 hospital employees in July and August 2018. We offered the post-shift survey to all EVS staff who participated in the air sampling survey. We also offered the post-shift survey to non-EVS staff working in departments where air samples were collected. Questions addressed eye, respiratory, and skin symptoms; nasal allergies, skin allergies, chronic bronchitis, emphysema, chronic obstructive pulmonary disease (COPD), asthma, and other diagnoses; smoking history; cleaning product use; hospital department assignment; stress outside of work; stress at work; and demographic information. Stress outside of work and stress at work were included as questions in the survey because recent studies indicate a potential association between psychosocial stress and respiratory symptoms [Rosenberg et al. 2014; Clougherty et al. 2009]. The survey was professionally translated into Spanish and offered in English or Spanish.

For eye, respiratory, and skin symptoms, we asked if employees had experienced any of the following symptoms in the previous four weeks: (1) nasal irritation (burning, itchy, runny nose); (2) sneezing; (3) throat irritation (burning, dry, sore throat); (4) eye irritation (burning, itchy, watery eyes); (5) cough; (6) wheezing or whistling in the chest; (7) chest tightness; (8) shortness of breath; (9) difficulty breathing; and (10) skin symptoms. When employees reported symptoms that occurred in the previous four weeks, we asked if their symptoms when away from work, either on their days off or when they were on vacation, were the same, worse, or better.

We also asked if employees had experienced any of the same symptoms (listed above) during their shift. When employees reported symptoms that occurred during their work shift, we asked (1) if their symptom had worsened during their shift; (2) what they were doing when the symptom first began; and (3) if they had that symptom upon arrival at work that day. Acute, cross-shift work-related symptoms were defined as symptoms that occurred during the participants' shift that were not present upon arrival at work that day. Symptoms that improved when the employees were away from work, either on their days off or when they were on vacation, were defined as work-related.

Statistical Analyses

All statistical analyses were performed using PC-SAS version 9.4 and JMP version 13.0 (SAS Institute, Cary, NC) and all plots were prepared in SigmaPlot (Version 14.0, Systat Software Inc., San Jose, CA). Because plots of the full-shift TWA exposure data for HP, PAA, and AA indicated the distributions were not normal, all full-shift TWA exposure measurements were log-transformed for all analyses. The mean, standard deviation, geometric mean, geometric standard deviation, and 95th percentile, overall and by department and sample type, were calculated using the NLMIXED procedure in SAS, which accounts for measurements below the limit of detection (LOD). The minimum variance unbiased estimator (MVUE) was used to estimate the mean (average) exposure for all analyses by department.

Individual Level Exposure Measurements

EVS staff participating in air sampling were assigned with their individual air sampling results. EVS with no air sampling results were assigned the average personal exposure for HP, PAA, and AA of EVS employees working in their department during their shift. Non-EVS staff were assigned with the average measurements for HP, PAA, and AA collected in their department during their shift. In departments where only AA measurements were collected, relationships between AA and PAA or HP were developed using data from areas where all three exposure measurements were collected to predict exposures to HP and PAA. The PROC REG procedure in SAS was used to model these relationships with measurements for AA as the predictor variable and HP or PAA as the outcome variable. Predicted values were used to calculate the HP and PAA averages by department to assign exposure for non-EVS staff working in areas of the hospital with only AA measurements.

Associations Between Acute Health Outcomes and Exposure Metrics: Individual Level Exposure

We explored associations between employee's exposure to HP, PAA, and AA and work-related acute, cross-shift symptoms using logistic regression. We used the American Conference of Governmental Industrial Hygienists' (ACGIH®) Additive Mixture Formula to estimate mixture exposures for the total mixture (TM) of HP, PAA, and AA as well as the oxidant exposure mixture (OM) of HP and PAA [ACGIH 2016]. Measured parts per million (ppm) concentrations of HP and AA were divided by their established OSHA Permissible Exposure Limit (PEL) and NIOSH Recommended Exposure Limit (REL) of 1 ppm for HP and 10 ppm for AA (Equations 1 and 2). Measured ppm concentrations of PAA were divided by 0.2 ppm, the occupational exposure limit proposed by multiple researchers [Gagnaire et al. 2002; Pechacek et al. 2015; Pacenti et al. 2010]. TM and OM exposure was determined using Eqs. (1) and (2),

$$TM = \frac{[HP]}{1\ ppm} + \frac{[PAA]}{0.2\ ppm} + \frac{[AA]}{10\ ppm} \quad (1)$$

$$OM = \frac{[HP]}{1\ ppm} + \frac{[PAA]}{0.2\ ppm} \quad (2)$$

where [HP], [PAA], and [AA] represent the measured full-shift TWA concentrations for HP, PAA, and AA.

The LOGISTIC procedure in SAS was used to examine associations of individual level exposure to HP, PAA, AA, TM, and OM; age; gender; smoking status; use of cleaning products containing sensitizers or irritants during an employee's shift; allergic status; and total stress; with work-related eye, upper airway, lower airway, and skin symptoms reported during an employee's shift.

Other sensitizer or irritant-containing cleaning products were defined as products containing quaternary ammonium compounds, bleach, phosphoric acid, sodium xylenesulfonate, or ethanolamines. Use of quaternary ammonium compounds, bleach, phosphoric acid, sodium xylenesulfonate, or ethanolamines was obtained from reported product use in the post-shift survey. Up to six different products containing sensitizers or irritants were reported, with two different products reported containing quaternary ammonium compounds, one product containing bleach, one product containing phosphoric acid, one product containing sodium xylenesulfonate, and one product containing ethanolamines. We assessed associations between acute cross-shift work-related symptoms and use of a combination of these products throughout the workday by using a sensitizer and irritant index value. A sensitizer and irritant product use during shift index value (0–6) was determined by adding the number of products containing sensitizers and irritants that an employee reported using during their shift on the day of sampling. For example, an employee who reported using three other cleaning products during their shift that contained phosphoric acid, bleach, and ethanolamines, respectively, was assigned a sensitizer and irritant index value of 3.

Allergic status was defined as reporting a previous diagnosis of nasal or sinus allergies (including hay fever) or skin allergy (eczema or any kind of skin allergy).

Total stress was defined as the average reported stress at work and stress outside of work in the previous four weeks, on a continuous scale from 0 to 10, where a score of 0–3 indicates low stress, 4–6 moderate stress, and 7–10 high stress [Elo et al. 2003; Clark et al. 2011].

Departmental Level Exposure Measurements

We also calculated the average exposure for each of the nine hospital departments where air sampling was performed using the NLMIXED procedure in SAS. EVS staff were assigned the average personal exposure measurements by department. In departments with no personal exposure measurements collected on EVS staff, EVS staff were assigned the average mobile exposure measurements by department. Non-EVS staff were assigned with the average measurements for HP, PAA, and AA collected in their department during their shift.

Associations Between Chronic Health Outcomes and Exposure Metrics: Departmental Level Exposure

All 77 survey participants worked in a department where air sampling was performed. We assessed associations between average departmental exposure and symptoms reported by staff. The LOGISTIC procedure in SAS was used to examine associations of departmental

level exposure to HP, PAA, AA, TM, and OM; age; gender; smoking status; use of cleaning products containing sensitizers and irritants in the previous four weeks; allergic status; and total stress; with work-related eye, upper airway, lower airway, and skin symptoms in the previous four weeks.

Similar methods as described for the acute, cross-shift symptoms, were used to define a sensitizer and irritant index value. Other sensitizer and irritant product use in the previous four weeks index value (0–6) was determined by adding the number of sensitizer and irritant products and frequency of product use, that an employee reported using during the previous four weeks. Frequency of product use was incorporated by multiplying each product used (n=1 for each respective product) by the factors assigned to reported frequency of use. The following factors were applied to weight reported product use by frequency: frequently=1, rarely=0.1, and never=0. For example, an employee who reported using a bleach product frequently, a quaternary ammonium product frequently, an ethanolamine product rarely, and a phosphoric acid product rarely, was assigned a sensitizer and irritant index value of: (1*1) + (1*1) + (1*0.1) + (1*0.1) = 2.2.

A positive allergic status was defined as reporting previous nasal or sinus allergies (including hay fever) or skin allergy (eczema or any kind of skin allergy) diagnosis.

Total stress was defined as the average reported stress at work and stress outside of work in the previous four weeks, on a scale from 0 to 10, where a score of 0–3 indicates low stress, 4–6 moderate stress, and 7–10 high stress [Elo et al. 2003; Clark et al. 2011].

Results

Major findings regarding hospital staff, use of a sporicidal product containing HP, PAA, and AA, and related exposure measurements are presented below. In general, we observed the sporicidal product containing HP, PAA, and AA was the main cleaning product used for all surface cleaning duties in areas sampled during the July and August 2018 survey.

August 2017 Bulk Sample Analysis

During our visits, we observed that EVS staff used automated dispensers designed to dilute the concentrated sporicidal product to its at-use pH of 2.7–4.0. We observed pH measurements of the diluted sporicidal product that ranged from 3.1–7.5. The product's safety data sheet (SDS) indicates the product should be diluted to a pH of 2.7–4.0. The highest pH (7.5) was measured in a sample collected from a dispenser that indicated the concentrated product was low and needed replacement. We observed staff using the automated dispensers to pour the sporicidal product directly into plastic bottles. The plastic bottles were then used to pour the product into buckets that contained cloth wipes. Buckets were equipped with a lid that was opened only when EVS staff needed to access cloths for cleaning. We observed that nitrile gloves were used routinely when working with cleaning products. Staff occasionally chose to also wear safety goggles or a surgical mask or a MOLDEX 2800N95 Series Particulate Respirator (Moldex® Culver City, CA) when dispensing or working with cleaning products.

July–August 2018 Bulk Sample Analysis
We collected 28 bulk samples from EVS cleaning carts. No hydrogen peroxide measurements were collected on July 31, 2018 because of a limited supply of reagents in the hydrogen peroxide test kit. Concentrations of peracetic acid and hydrogen peroxide measured in samples of the diluted product varied among cart samples and ranged from 900 parts per million (ppm) to 2100 ppm for peracetic acid and 3600 ppm to 7000 ppm for hydrogen peroxide (Appendix, Table A1).

We collected repeat measurements on three carts to assess if peracetic acid or hydrogen peroxide concentrations in the diluted product on EVS employee's carts varied throughout the shift. For the three carts that NIOSH staff collected multiple samples from throughout the shift, peracetic acid concentrations were consistent throughout the shift and varied from 1500 ppm to 1800 ppm (3 North cart); 1200 ppm to 1500 ppm (black cart); and 1500 ppm to 2100 ppm (3 South cart). Hydrogen peroxide concentrations were also consistent throughout the shift and ranged from 4800 ppm to 6000 ppm (3 North cart); 3600 ppm to 4800 ppm (black cart); and 6000 ppm to 7000 ppm (3 South cart) (Appendix A1).

Summary of July–August 2018 Air Sampling Results
Full-shift time-weighted average exposure levels for HP, PAA, and AA ranged from <3 parts per billion (ppb)–559 ppb for HP, <0.2 ppb–28 ppb for PAA, and <5 ppb–915 ppb for AA (Figure 1). The LODs were 2 micrograms (µg) of HP per sample, 0.2 µg of PAA per sample, and 1 µg of AA per sample. The average air concentrations measured on employees in each sampled department are provided in Table 1. The average air concentrations measured in each sampled department area are provided in Table 2. The highest personal exposures to the total mixture of HP, PAA, and AA were observed on EVS staff performing cleaning duties in labor and delivery, pediatrics, the 5th floor step-down unit, and float employees performing cleaning of discharged patient rooms (Table 1).

Currently, there is no OSHA PEL or NIOSH REL for exposure to the mixture of HP, PAA, and AA. Most exposure limit values are created for exposure to a single chemical substance [ACGIH 2016]. There are occupational exposure limits for exposure to HP or AA. The OSHA PEL and NIOSH REL is 1 ppm (1000 ppb) for exposure to HP and 10 ppm (10,000 ppb) for exposure to AA. All measurements for HP and AA were below their respective OSHA PELs and NIOSH RELs [NIOSH 2010] for exposure to HP or AA alone. There is currently no OSHA PEL or NIOSH REL for occupational exposure to PAA, however, several research groups have suggested 0.2 ppm as an exposure limit [Gagnaire et al. 2002; Pechacek et al. 2015; Pacenti et al. 2010]. ACGIH® developed a mixture formula that can be used when multiple chemical exposures occur simultaneously and have similar biological effects [ACGIH 2016]. The ACGIH® mixture formula was used to create the TM and OM used for the results presented below. HP and PAA are strong oxidants, and their mixture is listed as an asthmagen by the Association of Occupational and Environmental Clinics [AOEC 2015]. Asthmagens are substances that can cause asthma.

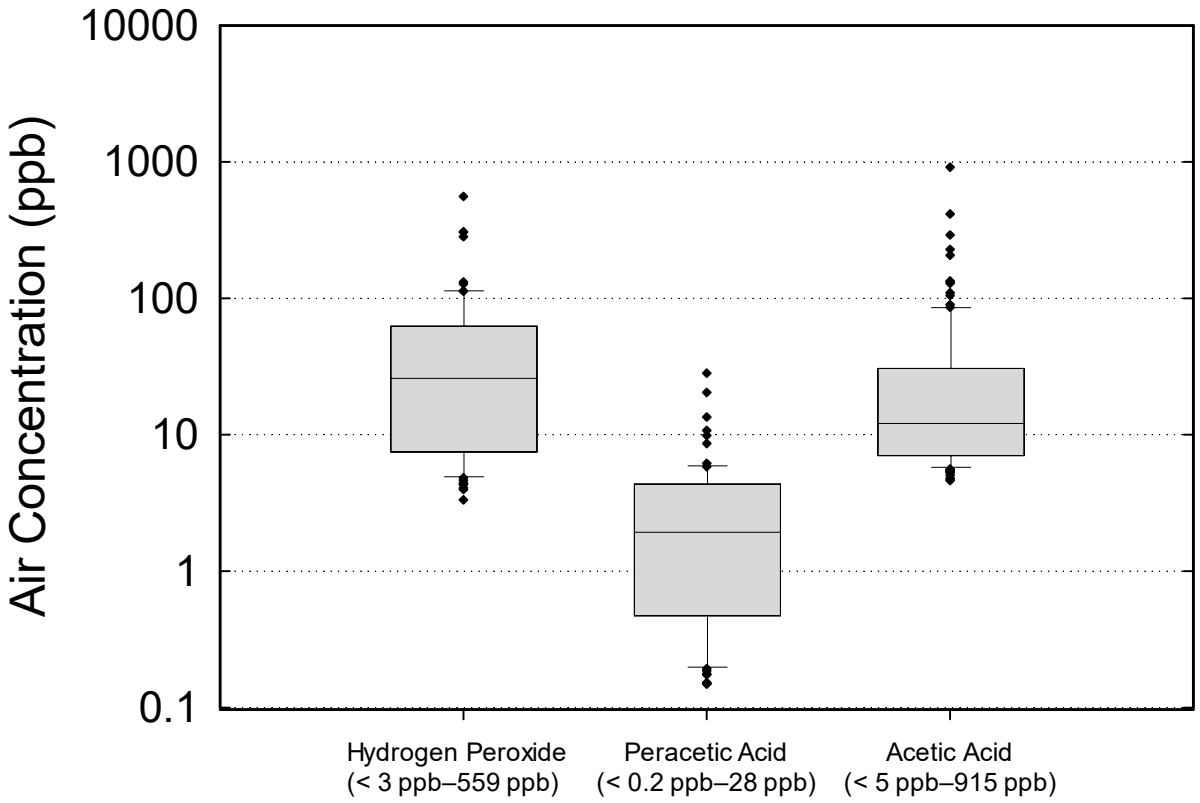

Figure 1. Box-plots of full-shift time-weighted average exposure levels of hydrogen peroxide (HP), peracetic acid (PAA), and acetic acid (AA), NIOSH survey, July and August 2018. Note: ppb=parts per billion. The box-plots illustrate each quartile with the lowest quartile shown as the line and hatch mark below the box, the second and third quartiles indicated by the shaded box, and the highest quartile indicated by the line and hatch mark above the boxes. The line within each box indicates the median air sample concentration. Outlier air samples are denoted by dots. The OSHA PEL and NIOSH REL is 1000 ppb (1 ppm) for hydrogen peroxide and 10,000 ppb (10 ppm) for acetic acid.

Table 1. Average (MVUE) and geometric mean (GM) EVS staff exposures and 95th percentile concentrations (in parts per billion) of hydrogen peroxide, peracetic acid, and acetic acid, by hospital work area, July and August 2018.

Hospital Area	Sample (N)	Hydrogen Peroxide			Peracetic Acid			Acetic Acid			OM		TM	
		MVUE (± SD)	GM (GSD)	95%ile	MVUE (± SD)	GM (GSD)	95%ile	MVUE (± SD)	GM (GSD)	95%ile	MVUE (± SD)	GM (GSD)	MVUE (± SD)	GM (GSD)
1st Floor Emergency Dept	Personal (n=6)	29.5 (±19.2)	24.9 (1.9)	81.7	1.4 (± 1.4)	1.0 (2.7)	3.6	35.2 (±36.7)	22.9 (2.9)	84.3	0.04 (±0.02)	0.03 (1.82)	0.04 (±0.02)	0.04 (1.76)
	Mobile (n=3)	68.5 (±19.6)	66.6 (1.3)	96.6	1.9 (± 0.3)	1.8 (1.1)	2.2	31.04 (±23.0)	25.4 (2.2)	54.3	0.08 (± 0.02)	0.08 (1.30)	0.09 (± 0.04)	0.08 (1.5)
2nd Floor ICU	Personal (n=0)	–	–	–	–	–	–	–	–	–	–	–	–	–
	Mobile (n=6)	61.0 (±16.1)	59.2 (1.3)	89.5	2.6 (± 1.4)	2.3 (1.7)	5.4	126.2 (±231.0)	36.2 (6.5)	915.1	0.08 (± 0.02)	0.07 (1.34)	0.09 (± 0.03)	0.08 (1.45)
3rd Floor Labor & Delivery	Personal (n=4)	90.5 (± 30.5)	86.7 (1.4)	127.7	5.3 (± 1.5)	5.0 (1.5)	8.6	102.5 (±137.7)	46.9 (4.7)	134.1	0.12 (± 0.03)	0.11 (1.34)	0.13 (± 0.04)	0.12 (1.37)
	Mobile (n=5)	63.1 (±38.5)	54.3 (1.9)	131.9	3.9 (± 1.5)	3.6 (1.5)	5.3	30.4 (± 42.6)	13.7 (4.5)	50.8	0.09 (± 0.04)	0.08 (1.66)	0.09 (± 0.04)	0.08 (1.62)
4th Floor Pediatrics	Personal (n=5)	89.3 (±89.3)	59.7 (2.8)	283.6	6.0 (± 2.2)	5.7 (1.4)	10.7	25.2 (±48.4)	5.4 (8.9)	74.4	0.12 (± 0.09)	0.09 (2.22)	0.12 (± 0.09)	0.10 (2.15)
	Mobile (n=0)	–	–	–	–	–	–	–	–	–	–	–	–	–
5th Floor Step Down Unit	Personal (n=5)	63.4 (± 69.4)	39.1 (3.1)	113.4	13.0 (± 14.2)	8.1 (3.1)	28.4	83.4 (±197.6)	7.0 (19.1)	207.1	0.13 (± 0.14)	0.08 (3.11)	0.14 (± 0.15)	0.09 (3.12)
	Mobile (n=1)	[A]308.0	–	–	[A]9.9	–	–	[A]416.0	–	–	[A]0.36	–	[A]0.40	–
6th Floor Medical-surgical	Personal (n=0)	–	–	–	–	–	–	–	–	–	–	–	–	–
	Mobile (n=3)	23.5 (±3.0)	23.4 (1.1)	26.1	1.9 (± 0.4)	1.9 (1.2)	2.3	31.5 (± 33.9)	19.5 (3.6)	69.1	0.03 (± 0.00)	0.03 (1.15)	0.04 (± 0.00)	0.04 (1.06)
7th Floor Medical-surgical	Personal (n=0)	–	–	–	–	–	–	–	–	–	–	–	–	–
	Mobile (n=4)	25.9 (± 11.0)	24.2 (1.5)	42.6	1.5 (± 0.8)	1.4 (1.8)	3.4	17.7 (± 22.4)	8.9 (4.2)	37.9	0.03 (± 0.01)	0.03 (1.48)	0.04 (± 0.01)	0.04 (1.42)
Float: Discharges	Personal (n=6)	168.1 (±150.3)	122.0 (2.5)	558.8	3.3 (± 1.7)	3.0 (1.7)	5.7	140.1 (± 75.2)	124.5 (1.7)	292.2	0.19 (± 0.15)	0.14 (2.26)	0.20 (± 0.16)	0.16 (2.21)
	Mobile (n=2)	[A]6.9-13.1	–	–	[A]1.4-1.7	–	–	[A]16.7-29.9	–	–	[A]0.01-0.02	–	[A]0.03-0.06	–
Public Restrooms & Discharges	Personal (n=3)	44.0 (±26.7)	38.6 (1.9)	93.8	4.1 (± 2.1)	3.8 (1.7)	5.8	67.8 (± 95.7)	24.7 (7.1)	110.1	0.07 (± 0.04)	0.06 (1.74)	0.07 (± 0.04)	0.06 (1.79)
	Mobile (n=3)	28.5 (± 12.7)	26.6 (1.6)	42.4	3.5 (± 1.2)	3.4 (1.4)	4.5	8.8 (± 12.0)	3.5 (6.4)	31.4	0.05 (± 0.02)	0.04 (1.50)	0.05 (± 0.02)	0.05 (1.42)

'–'indicates employee departments where no samples or taken or insufficient numbers of samples >LOD were collected to calculate MVUE, SD, GM, GSD, or 95%tile.
[A]Indicates employee departments with <2 measurements. In these departments, the minimum and maximum measurements replace the average (MVUE) calculations.

[B]Indicates employee departments where >70% of samples were <LOD. In these departments, the minimum and maximum measurements replace the average (MVUE) calculations. MVUE indicates minimum variance unbiased estimate. SD indicates one standard deviation, ± one standard deviation shown in parentheses. GM indicates geometric mean. GSD indicates geometric standard deviation, ± one geometric standard deviation shown in parentheses. 95%ile indicates 95th percentile. OM indicates the oxidant mixture defined by Equation 2. TM indicates the total mixture defined by Equation 1. Float: discharges=employees assigned to clean discharged patient rooms in multiple departments. Public Restrooms & Discharges=employees assigned to clean public restrooms and discharged patient rooms in multiple departments. ICU=intensive care unit.

Table 2. Average (MVUE) and 95th percentile area concentrations (in parts per billion) of hydrogen peroxide, peracetic acid, acetic acid, oxidant mixture, and total mixture by hospital area, July and August 2018.

Hospital Area	N	Hydrogen Peroxide			N	Peracetic Acid			N	Acetic Acid			N	OM		N	TM	
		MVUE (± SD)	GM (GSD)	95%ile		MVUE (± SD)	GM (GSD)	95%ile		MVUE (± SD)	GM (GSD)	95%ile		MVUE (± SD)	GM (GSD)		MVUE (± SD)	GM (GSD)
1st Floor Emergency Dept	12	4.4 (± 1.3)	4.6 (1.3)	7.3	12	0.2 (± 0.2)	0.1 (2.5)	0.6	12	8.9 (± 6.1)	7.3 (1.9)	20.7	12	0.01 (±0.0)	0.006 (± 1.34)	12	0.01 (± 0.0)	
2nd Floor ICU	2	[A]4.4-8.1	–	–	2	[A]0.2-1.1	–	–	6	11.6 (± 7.2)	9.9 (1.9)	20.1	2	[A]0.005-0.014	–	2	[A]0.007-0.016	–
2nd Floor ICU Pre-Op	0	–	–	–	0	–	–	–	4	8.0 (± 2.2)	7.7 (1.3)	10.7	0			0		
3rd Floor Anesthesia Admin	0	–	–	–	0	–	–	–	4	17.0 (± 9.3)	15.2 (1.7)	29.7	0	–	–	0	–	–
3rd Floor Labor & Delivery	6	6.9 (± 2.8)	6.4 (1.5)	12.0	6	0.6 (± 1.1)	0.2 (5.1)	2.4	12	11.2 (± 7.2)	9.4 (1.9)	31.4	6	0.01 (± 0.01)	0.008 (1.81)	6	0.01 (± 0.01)	0.009 (1.75)
4th Floor Pediatrics	2	[A]6.8-16.6	–	–	2	[A]0.2-2.4	–	–	6	11.3 (± 7.4)	9.5 (1.9)	23.6	2	[A]0.018 -0.019	–	2	[A]0.019-0.021	–
5th Floor Step Down Unit	2	[A]6.7-42.1	–	–	2	[A]0.5-5.7	–	–	6	12.8 (± 6.8)	11.4 (1.7)	25.4	2	[A]0.009 -0.07	–	2	[A]0.011-0.073	–
6th Floor Medical-Surgical	2	[A]7.5-16.8	–	–	2	[A]0.2-0.6	–	–	6	12.2 (± 6.6)	10.8 (1.7)	22.1	2	[A]0.009 -0.02	–	2	[A]0.010-0.022	–
7th Floor Medical-Surgical	2	[A]7.0-8.7	–	–	2	[A]0.3-0.7	–	–	6	9.2 (± 1.7)	10.5 (5.8)	21.4	2	[A]0.009 -0.012	–	2	[A]0.010-0.014	–
Diagnostic Imaging	0	–	–	–	0	–	–	–	4	[B]5.4-9.7	–	9.7	0	–	–	0	–	–
Pharmacy	0	–	–	–	0	–	–	–	4	6.7 (± 3.3)	6.2 (1.6)	9.8	0	–	–	0	–	–

–indicates areas where no samples or taken or insufficient numbers of samples > LOD were collected to calculate MVUE, SD, GM, GSD, or 95%tile. AIndicates areas with < 2 measurements. In these areas, the minimum and maximum measurements replace the average (MVUE) calculations. BIndicates areas where >70% of samples were < LOD. In these areas, the minimum and maximum measurements replace the average (MVUE) calculations. MVUE indicates minimum variance unbiased estimate. SD indicates one standard deviation, ± one standard deviation shown in parentheses. GM indicated geometric mean. GSD indicates geometric standard deviation, ± one geometric standard deviation shown in parentheses. 95%ile indicates 95th percentile. OM indicates the oxidant mixture defined by Equation 2. TM indicates the total mixture defined by Equation 1. ICU = intensive care unit.

Participant Demographics and Post-Shift Survey Results

A total of 77 current employees, including 55 EVS staff and 22 non-EVS staff, completed the post-shift survey. The job groups of the non-EVS participants can be seen in Table 3. Participant demographics can be seen in Table 4. The median age for both EVS and non-EVS participants were similar with a median age among EVS participants of 51 years (range: 23 years to 70 years) and a median age among non-EVS participants of 42 years (range: 28 years to 58 years) (Table 4). Most participants were Hispanic (73% EVS and 45% non-EVS). The median tenure at the hospital was 6.4 years for EVS participants and 12.0 years for non-EVS participants. Gender and smoking history were similar between the two groups. Most participants were female (75% EVS and 82% non-EVS) and never smokers (76% EVS and 82% non-EVS).

Table 3. Job groups of non-EVS post-survey participants, N=22, July and August 2018

Job Group	n (%)
Nursing staff*	13 (59%)
Other patient care staff†	4 (18%)
Administrative staff‡	3 (14%)
Pharmacists	2 (9%)

Note: EVS=environmental services staff
***Nursing Staff includes Staff Nurses and Registered Nurses.**
†Other Patient Care Staff includes Case Managers, Respiratory Technicians, Radiology Technicians and Radiology Assistants.
‡Administrative Staff includes Unit Secretaries and Clerks.

Table 4. Demographic characteristics of survey participants, NIOSH survey, July and August 2018

Characteristic	All Participants (N=77)	EVS (n=55)	Non-EVS (n=22)
Age, years, median (range)	46 (23–70)	51 (23–70)	42 (28–58)
Tenure, years, median (range)	6.9 (0.1-28.8)	6.4 (0.1–28.8)	12 (0.3–21.7)
Male, n (%)	18 (23%)	14 (25%)	4 (18%)
Race, n (%)			
Hispanic	50 (65%)	40 (73%)	10 (45%)
White	14 (18%)	7 (13%)	7 (32%)
Asian	6 (8%)	4 (7%)	2 (9%)
Unknown†	5 (6%)	3 (5%)	2 (9%)
Black	2 (3%)	1 (2%)	1 (5%)
Smoking status, n (%)			
Current	5 (6%)	4 (7%)	1 (5%)
Former	12 (16%)	9 (16%)	3 (14%)
Never	60 (78%)	42 (76%)	18 (82%)

Notes: EVS=Environmental Services Staff; Non-EVS=Case Manager, Staff Nurses, Registered Nurses, Respiratory Technicians, Unit Secretaries, Clerks, Radiology Technicians, Radiology Assistants, Pharmacy
†Includes participants who refused to indicate a race

All participants' responses to questions about self-reported symptoms and diagnoses can be seen in Table 5. The most commonly reported symptoms occurring during their shift, or in the previous four weeks, were nasal irritation and eye irritation. Nasal irritation occurring during the employee's work shift was reported by 39%, and eye irritation occurring during the employee's work shift was reported by 43% of all participants (Table 5). Similarly, nasal irritation occurring in the previous four weeks was reported by 58%, and eye irritation was reported by 66% of all participants.

Some reported symptoms were work-related. Acute, cross-shift work-related mucous membrane irritation (defined as nasal and/or eye irritation) was reported by 48% (n=37/77) of total post-shift survey participants and 62% (n=34/55) of EVS staff survey participants. Work-related mucous membrane irritation in the previous four weeks was reported by 57% (n=44/77) of total post-shift survey participants and 69% (n=38/55) of EVS staff survey participants. Acute work-related lower airway symptoms such as cough, wheeze, chest tightness, shortness of breath or difficulty breathing were reported in 36% (n=28/77) of total post-shift survey participants and 45% (n=25/55) of EVS staff survey participants. Work-related lower airway symptoms such as cough, wheeze, chest tightness, shortness of breath or difficulty breathing in the previous four weeks were reported in 44% (n=34/77) of total post-shift survey participants and 55% (n=30/55) of EVS staff survey participants.

Nasal irritation, throat irritation, eye irritation, and shortness of breath were the most frequently reported work-related symptoms in the post-shift survey of acute, cross-shift symptoms. Thirty-two percent of post-shift survey participants reported work-related nasal irritation, 27% work-related throat irritation, 40% work-related eye irritation, and 21% work-related shortness of breath during their shift. Similarly, nasal irritation (43%), sneeze (36%), throat irritation (36%), and eye irritation (45%) were the most frequently reported work-related symptoms in the post-shift survey of symptoms occurring in the previous four weeks. Work-related cough, wheeze, or shortness of breath in the previous four weeks was reported by 27%, 23%, and 23% of participants, respectively.

Table 5. Symptoms, self-reported diagnoses, and total stress reported by all post-shift survey participants (N=77), July and August 2018

Health Outcome	Overall symptoms, n (%)	Work-related*, n (%)
Symptoms during shift		
Nasal irritation	30 (39%)	25 (32%)
Eye irritation	33 (43%)	31 (40%)
Sneeze	18 (23%)	14 (18%)
Throat irritation	26 (34%)	21 (27%)
Cough	15 (19%)	10 (13%)
Wheeze or whistling in the chest	10 (13%)	8 (10%)
Chest tightness	6 (8%)	4 (5%)
Shortness of breath	16 (21%)	16 (21%)
Difficulty breathing	5 (6%)	5 (6%)
Lower airway symptoms (cough, wheeze, chest tightness, shortness of breath, or difficulty breathing)	31 (40%)	28 (36%)
Skin symptoms	6 (8%)	4 (5%)
Symptoms in previous 4 weeks		
Nasal irritation	45 (58%)	33 (43%)
Eye irritation	51 (66%)	35 (45%)
Sneeze	43 (56%)	28 (36%)
Throat irritation	39 (51%)	28 (36%)
Cough	29 (38%)	21 (27%)
Wheeze or whistling in the chest	26 (34%)	18 (23%)
Chest tightness	17 (22%)	12 (16%)
Shortness of breath	24 (31%)	18 (23%)
Difficulty breathing	17 (22%)	11 (14%)
Lower airway symptoms (cough, wheeze, chest tightness, shortness of breath, or difficulty breathing)	42 (55%)	34 (44%)
Skin symptoms	19 (25%)	16 (21%)
Diagnoses		
Asthma		
Ever	9 (12%)	
Current	5 (7%)	
Nasal or sinus allergies	23 (30%)	
Eczema or any kind of skin allergy	7 (9%)	
Chronic bronchitis	7 (9%)	
Emphysema	0 (0%)	
COPD	0 (0%)	
Total Stress	5.0**	

***Work-related acute, cross-shift symptoms defined as symptoms that occurred during the participants' shift**

that were not present upon arrival at work that day. Work-related symptoms in the previous four weeks were defined as symptoms that improved away from the facility, either on days off or on vacation. **Total stress is reported as the average for all participants, on a scale of 0–10. COPD=Chronic Obstructive Pulmonary Disease.

Summary of July and August 2018 Post-Shift Survey of Acute, Cross-Shift Symptoms and Associations with Exposure to HP, PAA, AA, OM, and TM

We explored associations between log-transformed exposure to single chemical vapors as well as mixtures of the chemical constituents in the sporicidal product (LnHP, LnPAA, LnAA, LnOM, and LnTM) and acute, cross-shift symptoms occurring during the work shift using logistic regression. We also explored associations between age, gender, tenure, smoking status, and use of cleaning products containing sensitizers and irritants during the employee's work shift, allergic status, total stress, and work-related acute symptoms using logistic regression (Appendix, Table A2). Work-related acute mucous membrane irritation symptoms, specifically nasal and eye irritation, as well as shortness of breath, were significantly associated with exposure to the OM of HP and PAA, and TM of HP, PAA, and AA, after adjusting for age, gender, smoking status, use of cleaning products containing known asthmagens during the employee's work shift, allergic status, and total stress (Figure 2; Table 6). Additionally, work-related acute, cross-shift wheeze was significantly associated with increases in exposure to HP, indicating an increase in symptoms with increasing exposure to HP, one of the constituents in the sporicidal product. Acute, cross-shift chest tightness and skin symptom results are not reported in Figure 2 and Table 6 below because the logistic regression model could not reliably estimate odds ratios and confidence intervals for these health endpoints because of few survey participants reporting these symptoms during their shift.

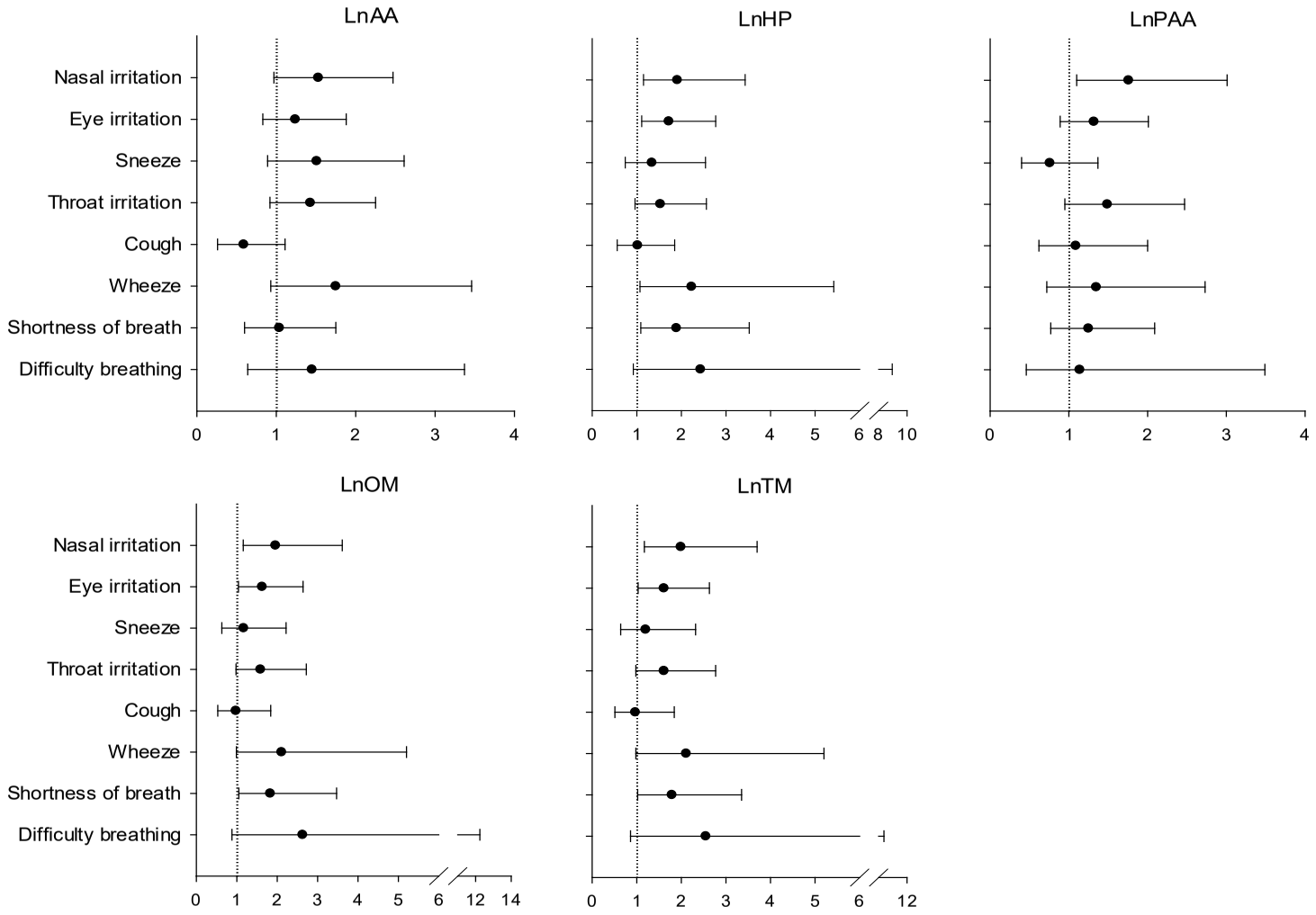

Figure 2. Adjusted odds ratios and 95% confidence intervals for eye, upper airway, and lower airway symptoms reported as occurring during employees' shift per increase in exposure to LnAA, LnHP, LnPAA, LnOM, and LnTM in July and August 2018. Ln indicates natural log-transformed measurements of AA, HP, PAA, OM, and TM respectively. OM indicates the mixture of HP and PAA using the ACGIH mixture formula. TM indicates the mixture of HP, PAA, and AA using the ACGIH mixture formula.

Table 6. Adjusted odds ratios** for acute, cross-shift symptoms and exposure to hydrogen peroxide, peracetic acid, acetic acid, oxidant mixture, and total mixture in July and August 2018.

Symptom	LnHP (95% CI)	LnPAA (95% CI)	LnAA (95% CI)	LnOM (95% CI)	LnTM (95% CI)
Nasal irritation*†	**1.91 (1.15–3.43)**	**1.76 (1.10–3.01)**	1.53 (0.97–2.47)	**1.96 (1.16–3.61)**	**1.99 (1.17–3.70)**
Sneeze	1.34 (0.74–2.54)	0.76 (0.40–1.37)	1.51 (0.89–2.61)	1.17 (0.63–2.22)	1.20 (0.64–2.32)
Eye irritation*†	**1.72 (1.11–2.77)**	1.32 (0.89–2.01)	1.24 (0.83–1.88)	**1.63 (1.04–2.64)**	**1.61 (1.03–2.63)**
Throat irritation	1.53 (0.96–2.56)	1.49 (0.95–2.47)	1.43 (0.92–2.25)	1.59 (0.98–2.72)	1.61 (0.98–2.77)
Cough	1.02 (0.56–1.85)	1.09 (0.62–2.00)	0.59 (0.26–1.11)	1.08 (0.61–1.94)	1.07 (0.60–1.95)
Wheeze	**2.23 (1.07–5.42)**	1.35 (0.72–2.73)	1.75 (0.93–3.46)	2.11 (0.99–5.20)	2.11 (0.98–5.20)
Shortness of breath*†	**1.89 (1.09–3.52)**	1.25 (0.77–2.09)	1.04 (0.60–1.75)	**1.83 (1.05–3.47)**	**1.79 (1.02–3.35)**
Difficulty breathing	2.43 (0.92–8.96)	1.14 (0.46–3.49)	1.45 (0.64–3.37)	2.63 (0.88–12.24)	2.55 (0.86–11.19)

Note: Ln indicates log-transformed measurements of AA, HP, PAA, OM, and TM respectively. TM=total mixture defined using the ACGIH additive mixture formula (hydrogen peroxide, peracetic acid, and acetic acid); OM=oxidant mixture defined using the ACGIH additive mixture formula (hydrogen peroxide, and peracetic acid).
Exposures that were significantly associated with work-related acute symptoms are noted in bold.
***Indicates symptoms significantly positively associated with increased exposure to the oxidant mixture.**
†Indicates symptoms significantly positively associated with increased exposure to the total mixture.
****The adjusted odds ratios represent the change for every natural log parts per billion change in exposure measurements. An adjusted odds ratio greater than one indicates a significant increase in work-related symptoms for an increase in exposure, after adjusting for age, gender, tenure, smoking status, and use of cleaning products containing sensitizers and irritants during the employee's work shift, allergic status, and total stress.**

Summary of July and August 2018 Post-Shift Survey of Symptoms in the Previous 4 weeks and Associations with Departmental Exposure to HP, PAA, AA, OM, and TM

We explored associations between departmental exposure to single chemical vapors as well as mixtures of the chemical constituents in the sporicidal product (LnHP, LnPAA, LnAA, LnOM, and LnTM) and symptoms occurring during the previous four weeks using logistic regression. We also explored associations between age, gender, tenure, smoking status, and frequency of use of cleaning products containing sensitizers and irritants, allergic status, total stress and work-related symptoms in the previous four weeks using logistic regression (Appendix, Table A3). Work-related mucous membrane irritation symptoms in the previous four weeks, specifically nasal and eye irritation, were significantly associated with departmental exposure to the oxidant mixture of HP and PAA, and total mixture of HP, PAA, and AA, after adjusting for age, gender, smoking status, frequency of use of cleaning products containing sensitizers and irritants, allergic status, and total stress (Figure 3; Table 7). Additionally, work-related nasal irritation, eye irritation, and sneeze in the previous four weeks were significantly associated with increases in departmental exposure to PAA, indicating an increase in symptoms with increasing exposure to PAA, one of the constituents in the sporicidal product.

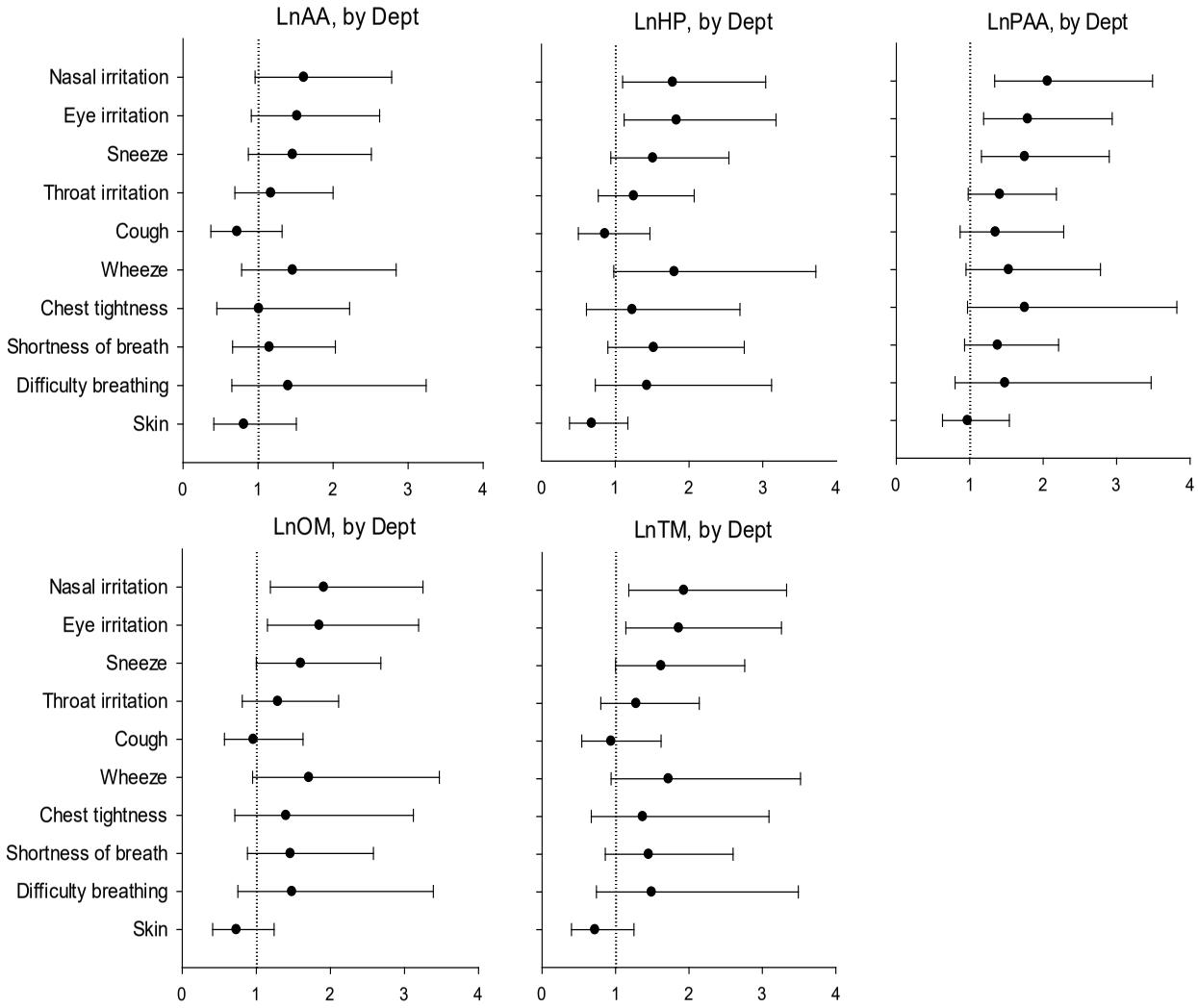

Figure 3. Adjusted odds ratios and 95% confidence intervals for work-related eye, upper airway, lower airway, and skin symptoms reported as occurring in the previous four weeks per increase in exposure to LnAA, LnHP, LnPAA, LnOM, and LnTM. Ln indicates natural log-transformed measurements of AA, HP, PAA, OM, and TM respectively. OM indicates the mixture of HP and PAA using the ACGIH mixture formula. TM indicates the mixture of HP, PAA, and AA using the ACGIH mixture formula.

Table 7. Adjusted odds ratios** for symptoms in the previous four weeks and exposure to hydrogen peroxide, peracetic acid, acetic acid, oxidant mixture, and total mixture in July and August 2018

Symptom	LnHP (95% CI)	LnPAA (95% CI)	LnAA (95% CI)	LnOM (95% CI)	LnTM (95% CI)
Nasal irritation*†	**1.78 (1.10–3.04)**	**2.06 (1.34–3.49)**	1.61 (0.96–2.78)	**1.91 (1.19–3.25)**	**1.93 (1.18–3.33)**
Sneeze	1.51 (0.94–2.54)	**1.75 (1.16–2.90)**	1.46 (0.87–2.51)	1.60 (1.00–2.68)	1.62 (1.00–2.76)
Eye irritation*†	**1.83 (1.12–3.18)**	**1.79 (1.19–2.94)**	1.52 (0.91–2.62)	**1.85 (1.15–3.19)**	**1.86 (1.14–3.26)**
Throat irritation	1.25 (0.77–2.07)	1.41 (0.98–2.18)	1.17 (0.69–2.00)	1.29 (0.81–2.11)	1.28 (0.80–2.14)
Cough	0.86 (0.50–1.47)	1.35 (0.87–2.28)	0.72 (0.37–1.32)	0.96 (0.57–1.63)	0.94 (0.54–1.62)
Wheeze	1.80 (0.98–3.72)	1.53 (0.95–2.78)	1.46 (0.78–2.84)	1.71 (0.95–3.47)	1.72 (0.94–3.52)
Chest tightness	1.23 (0.61–2.69)	1.75 (0.97–3.82)	1.01 (0.45–2.22)	1.40 (0.71–3.12)	1.37 (0.67–3.09)
Shortness of breath	1.52 (0.90–2.75)	1.38 (0.93–2.21)	1.15 (0.66–2.03)	1.46 (0.88–2.58)	1.45 (0.86–2.60)
Difficulty breathing	1.43 (0.73–3.12)	1.48 (0.80–3.47)	1.40 (0.65–3.24)	1.48 (0.75–3.39)	1.49 (0.74–3.49)
Skin symptoms	0.68 (0.38–1.17)	0.97 (0.63–1.54)	0.81 (0.41–1.51)	0.73 (0.41–1.24)	0.72 (0.40–1.25)

Note: Ln indicates log-transformed measurements of AA, HP, PAA, OM, and TM respectively. TM=total mixture defined using the ACGIH additive mixture formula (hydrogen peroxide, peracetic acid, and acetic acid); OM=oxidant mixture defined using the ACGIH additive mixture formula (hydrogen peroxide, and peracetic acid).

Exposures that were significantly associated with work-related acute symptoms are noted in bold.

*** Indicates symptoms significantly positively associated with increased exposure to the oxidant mixture.**

† Indicates symptoms significantly positively associated with increased exposure to the total mixture.

**** The adjusted odds ratios represent the change for every natural log parts per billion change in exposure measurements. An adjusted odds ratio greater than one indicates a significant increase in work-related symptoms for an increase in exposure, after adjusting for age, gender, tenure, smoking status, and frequency of use of cleaning products containing sensitizers and irritants in the previous four weeks, allergic status, and total stress.**

Discussion

Hospital staff using the product containing HP, PAA, and AA, or working in areas where the product containing HP, PAA, and AA was used, reported upper and lower airway symptoms occurring during their shift and in the previous four weeks. Symptoms were associated with exposure to the mixture of vapors from the sporicidal product.

Overall, nose and eye symptoms were the most commonly reported work-related symptoms among hospital staff. Occupational upper respiratory disease such as allergic rhinitis (hay fever, nasal allergies) and sinusitis is often more prevalent than occupational asthma and several studies suggest that rhinosinusitis might precede or occur with lower respiratory symptoms and asthma. asthma [Shaaban et al. 2008; EAACI Task Force on Occupational Rhinitis et al. 2008; Rondón et al. 2012, 2017; Sahay et al. 2016; Siracusa et al. 2000; Park et al. 2012]. Additionally, upper respiratory involvement (e.g., rhinitis, sinusitis) can result in suboptimal control of asthma. The common airway hypothesis suggests that occupational upper disease indicates a risk for lower airway involvement [Siracusa et al. 2000; Park et al. 2012; Walusiak 2006; Bascom et al. 2007]. Over two-thirds of (17 of 28; 68%) participants who reported work-related acute, cross-shift lower respiratory symptoms also reported acute, cross-shift nasal symptoms and almost three-quarters (25 of 34; 74%) of participants who reported work-related lower respiratory symptoms in the previous four weeks also reported work-related nasal symptoms in the previous four weeks.

Our results demonstrate that exposure to vapors from the sporicidal product containing HP, PAA, and AA contributed to work-related acute, cross-shift eye and airway symptoms as well as work-related eye and airway symptoms in the previous four weeks in hospital staff. The results of our evaluation are consistent with previous studies that have reported an increased risk for chronic bronchitis and work-related rhinitis and asthma in workers exposed to cleaning and disinfectant chemicals [Maçãira et al. 2007; Rosenman et al. 2003; Vizcaya et al. 2011; Charles, Loomis, and Demissie 2009]. We observed health effects among cleaning staff at exposure levels below established occupational exposure limits. Because both HP and PAA are strong oxidants, the mixture of HP and PAA potentially contributed to the eye and airway symptoms reported by cleaning staff at the relatively low levels of measured exposures.

The 2008 Centers for Disease Control and Prevention (CDC) Healthcare Infection Control Practices Advisory Committee (HICPAC) Guidelines recommend that each worker be informed of the possible health effect(s) of his or her exposure to chemicals [CDC 2008]. Specifically, employees should be educated on the documented health risks from exposure to HP, AA and PAA, as well as chemicals found in other cleaning products used at the hospital. This information should be consistent with SDSs, Environmental Protection Agency regulations, and OSHA requirements and identify areas and tasks where there is the potential for exposure. We note the Association of Occupational and Environmental Clinics (AOEC) in 2015 listed this sporicidal product as an asthmagen, or a substance that causes asthma [AOEC 2015].

We observed some EVS staff using surgical masks or a MOLDEX 2800N95 Series Particulate Respirator (Moldex® Culver City, CA) for the purpose of respiratory protection while dispensing or working with cleaning products. However, these types of masks do not provide adequate, validated respiratory protection while working with products that release gases or chemical vapors. Specifically, the MOLDEX 2800N95 respirators' effectiveness at mitigating worker exposure to organic vapors associated with the cleaning products in use at this hospital has not been validated.

We recommend that company management pursue the actions listed below to reduce employee exposure to sporicidal products containing HP, PAA, and AA. Because employees are most familiar with the areas and tasks involved, we recommend that management involve employees that perform the work duties in each respective area when enacting any actions described below. A committee of EVS staff, patient care staff, infection preventionists, and occupational health and safety representatives, should be convened when new cleaners and sporicidal disinfectants are chosen for the facility. Acquiring buy-in from these different groups before investment is key to implementing a new cleaning product or system. Labor-management health and safety meetings are also an opportune environment to discuss department-specific recommendations and develop an action plan. Many of our recommendations come from the CDC's HICPAC, which developed a Guideline for Disinfection and Sterilization in Healthcare Facilities in 2008 [CDC 2008]. This HICPAC Guideline acknowledges that irritant and allergic effects can occur with disinfectant chemical air concentrations at levels below OSHA or NIOSH exposure limits [CDC 2008]. HICPAC recommends that controls be used to minimize exposure to disinfectants, including elimination or substitution of the chemical, engineering or administrative controls, or the use of personal protective equipment. Additional information is provided in the Recommendations section, below.

Conclusions

In summary, acute eye symptoms and upper and lower respiratory symptoms occurring during an employee's work shift and in the previous four weeks were common among hospital staff. Hospital staff exposed to vapors from OxyCide®, a disinfectant cleaner that is one of a group of sporicidal products marketed under various trade names that contain HP, PAA, and AA, reported acute eye, airway, and skin symptoms, as well as eye, and airway symptoms in the previous four weeks at low levels of measured exposures. Increased exposure to HP, PAA, and AA was significantly associated with increases in work-related eye, and upper and lower airway symptoms after adjusting for age, gender, smoking status, use of cleaning products containing sensitizers and irritants, allergic status, and total stress. Work-related acute, cross-shift mucous membrane irritation symptoms, specifically nasal and eye irritation, as well as shortness of breath were significantly associated with increased exposure to HP, PAA, and AA, indicating an increase in symptoms with increasing exposure to the mixture of vapors from the sporicidal product. Wheeze during an employee's work shift was also significantly associated with increases in exposure to vapors from the sporicidal product, specifically with increases in exposure to HP. Work-related mucous

membrane symptoms in the previous four weeks, specifically nasal and eye irritation, in the previous four weeks were also significantly associated with increases in departmental exposure to HP, PAA, and AA, indicating an increase in symptoms with increasing exposure to vapors from the sporicidal product. Additionally, work-related nasal irritation, sneeze, and eye irritation in the previous four weeks were significantly associated with increases in departmental exposure to PAA, indicating an increase in symptoms with increasing exposure to PAA, one of the constituents in the sporicidal product. All full-shift TWA air samples for HP and AA were below established occupational exposure limits. Our results indicate a need to (1) monitor eye, respiratory, and skin symptoms among hospital cleaning staff using any cleaning products containing a mixture of HP, PAA, and AA, and (2) use a combination of engineering, administrative, and PPE controls to reduce employee exposures.

Recommendations

Our recommendations are based on an approach known as the hierarchy of controls. This approach groups actions by how effective they are at removing or reducing hazards. In most cases, the primary approach is to eliminate hazardous materials or processes, and to install engineering controls to reduce exposure or shield employees. Administrative measures and personal protective equipment might be needed until such engineering controls are in place, or if engineering controls are not effective or feasible. Hospital management has already taken some steps to minimize employee exposure to the sporicidal product containing HP, PAA, and AA, and address employee concerns. Below, we provide additional recommendations in the continued effort to improve employee health and safety.

Elimination or Substitution

A primary approach to minimizing exposure risk is to eliminate hazardous materials or processes. Sporicidal disinfectants are an important part of reducing healthcare-acquired infections. However, the choice to use sporicidal disinfectants in specific areas of the hospital should be prudent and reflect the level of risk of a healthcare-acquired infection. We observed the sporicidal product containing HP, PAA, and AA being used by cleaning staff on surfaces throughout the hospital, including surfaces in non-patient areas. HICPAC provides recommendations for when and where sterilization with sporicides versus disinfection with high- and low-level disinfectants should occur in healthcare facilities [CDC 2008]. Exposure to vapors containing HP, PAA, and AA could be reduced by substituting sporicidal products containing HP, PAA, and AA with intermediate or low-level disinfectants when cleaning noncritical items or surfaces in non-patient areas. HICPAC states that detergent and water are adequate for cleaning surfaces in non-patient care areas. We recommend sporicidal products containing HP, PAA, and AA, not be used in non-patient care areas such as in public bathrooms, pharmacy, or administrative offices.

Engineering Controls

Engineering controls can reduce employees' exposures by lowering air concentrations with increased ventilation or by placing a barrier between the hazard and the employee. Engineering controls protect employees effectively without placing primary responsibility of implementation on the employee.

1. Ensure the dispensers for the sporicidal product containing HP, PAA, and AA are calibrated to effectively dilute the product to a pH of 2.7–4.0. If the sporicidal product is not effectively diluted, a pH of less than 2.7 might increase skin, eye, and respiratory symptoms in exposed employees.
2. Ensure all heating, ventilation, and air-conditioning systems are functioning well and meet all applicable ASHRAE standards for ventilation of health care facilities [ASHRAE 2017].

Administrative Controls

Administrative controls refer to employer-dictated work practices and policies to reduce or prevent hazardous exposures. Their effectiveness depends on employer commitment and employee acceptance. Regular monitoring and reinforcement are necessary to ensure that policies and procedures are followed consistently.

1. Minimize use of sporicidal products containing HP, PAA, and AA, in non-patient care areas.
2. Ensure employees understand potential hazards in the workplace and how to protect themselves. OSHA's Hazard Communication Standard, also known as the "Right to Know Law" [29 CFR 1910.1200] requires that employees are informed and trained on potential work hazards and associated safe practices, procedures, and protective measures. Ensure employees have access and are informed of potential hazards and trained on the associated safe practices per the information found in the cleaning products' SDSs. The 2008 HICPAC Guideline recommends each worker be informed of the possible health effect(s) of his or her exposure to chemicals. Specifically, employees should be educated on the documented health risks from exposure to HP, AA and PAA, as well as chemicals found in other cleaners at the hospital. This information should be consistent with SDSs, Environmental Protection Agency regulations, and OSHA requirements and identify areas and tasks where there is the potential for exposure. These trainings should be offered in English and Spanish.
3. We recommend management implement a reporting system that would allow employees to report work-related symptoms, with the option to remain anonymous for employees who do not wish to be identified. As a performance indicator for disinfection and sterilization, HICPAC recommends that healthcare facilities develop a mechanism for the reporting of all adverse health events potentially resulting from exposure to sporicidal disinfectants and sterilants. These reports should be reviewed regularly, and the facility should implement controls to prevent future exposures.
4. Health and safety concerns related to cleaning and disinfecting products should be regularly evaluated. An annual post-shift survey of acute symptoms might be a useful tool for (1) alerting management to symptoms experienced by cleaning staff and (2) identifying areas of the hospital where symptoms might be more commonly reported, and exposures might be higher. Because a number of post-shift survey participants in our survey chose to have the survey administered in Spanish, the annual post-shift

survey should also be professionally translated and offered in Spanish. Such a system can allow employees with symptoms related to cleaning or disinfecting products to be offered relocation to an area or department of the hospital with lower risk of exposure to sporicidal disinfectants. This type of evaluation can also help the facility identify additional controls to reduce employee exposure.

5. Employees should report new, persistent, or worsening symptoms to their personal healthcare provider and, as instructed by their employer, to a designated individual at their workplace. An individualized management plan (such as assigning an affected employee to a different work location) is sometimes required as indicated by medical findings and recommendations of the physician. Employees with symptoms should provide their personal physicians or other healthcare providers with a copy of this report.
6. A team approach should be used when introducing a new cleaning product or system. A committee of EVS staff, patient care staff, infection preventionists, and occupational health and safety representatives should be convened when new cleaners and sporicidal disinfectants are chosen for the facility. Acquiring buy-in from these different groups before investment is key to implementing a new cleaning product or system. A trial period with a new cleaning system or product, with selected trial departments or areas of the hospital, could be used to acquire feedback from stakeholders, including EVS staff, to evaluate new cleaning systems or products. Evaluation of a new cleaning system or product should consider effectiveness, cost, and employee health and safety concerns.

Personal Protective Equipment

Personal protective equipment is the least effective means for controlling hazardous exposures. Proper use of personal protective equipment requires a comprehensive program and a high level of employee involvement and commitment. The right personal protective equipment must be chosen for each hazard. Supporting programs such as training, change-out schedules, and medical assessment might be needed. Personal protective equipment should not be the sole method for controlling hazardous exposures. Rather, personal protective equipment should be used until effective engineering and administrative controls are in place.

1. Require employees to wear extended cuff nitrile gloves or rubber gloves when using the sporicidal product containing HP, PAA, and AA, and goggles or a face shield while dispensing and pouring the product into or out of the bucket on their cleaning cart.

Appendix A: Supplemental Analyses

Associations of age, gender, smoking status, allergic status, use of cleaning products containing sensitizers and irritants, and total stress, with work-related eye, upper airway, lower airway, and skin symptoms reported during an employee's shift

We used the LOGISTIC procedure in SAS to examine associations of age, gender, smoking status, allergic status, use of cleaning products containing sensitizers and irritants during an employee's shift, and total stress, with work-related eye, upper airway, lower airway, and skin symptoms reported during an employee's shift. Results can be seen in Table A2 below.

Smoking status and allergic status were significantly associated with acute, cross-shift sneeze (Table A1). Use of products containing sensitizers and irritants during an employee's shift was significantly associated with acute, cross-shift nasal irritation, sneeze, and difficulty breathing. Total reported stress was significantly associated with acute, cross-shift nasal irritation, throat irritation, and shortness of breath. All covariates seen in Table A2 below were included in the adjusted models reported in Figure 2 and Table 6 in the main body of the report.

Associations of age, gender, smoking status, allergic status, use of cleaning products containing sensitizers and irritants, and total stress, with work-related eye, upper airway, lower airway, and skin symptoms reported during an employee's shift

We used the LOGISTIC procedure in SAS to examine associations of age, gender, smoking status, allergic status, use of cleaning products containing sensitizers and irritants in the previous four weeks, and total stress, with work-related eye, upper airway, lower airway, and skin symptoms in the previous four weeks. Results can be seen in Table A3 below.

Smoking status was significantly associated with sneeze in the previous four weeks (Table A2). Age was significantly associated with throat irritation in the previous four weeks. Use of products containing sensitizers and irritants during an employee's shift was significantly associated with difficulty breathing in the previous four weeks. Total reported stress was significantly associated with chest tightness and skin symptoms. All covariates seen in Table A3 below were included in the adjusted models reported in Figure 3 and Table 7 in the main body of the report.

Table A1. Peracetic acid and hydrogen peroxide measurements of diluted OxyCide® product, July–August 2018

Date	Dispenser Location	Cart ID	Cart Fill	Sample Collection Time	Peracetic Acid (ppm)	Hydrogen Peroxide (ppm)
7/31/18	7 South	7-Disney	12:45	14:10	900	—
7/31/18	4 North	4-North	7:30	13:39	1800	—
7/31/18	7 South	7-South	10:00	14:04	1500	—
7/31/18	7 North	7-2	9:30	14:08	1800	—
7/31/18	6 South	6-South	—	14:00	1500	—
7/31/18	5 South	5-2	7:30	13:43	1500	—
7/31/18	5 North	6470	7:30	13:47	900	—
7/31/18	6 North	D9	7:30	13:57	1500	—
7/31/18	3 North	3-3	7:30	13:29	1500	—
7/31/18	6 South	6-2	7:30	13:53	900	—
7/31/18	2 South	2-2	7:30	13:26	1200	—
7/31/18	2 North	2-Middle	7:45	13:19	1500	—
7/31/18	3 North	3-North	7:30	13:23	1800	—
7/31/18	2 North	2-North	7:30	13:12	1800	—
7/31/18	4 North	4-3	7:30	13:33	1800	—
7/31/18	5 North	5-3	7:30	13:47	1200	—
8/1/18	3 North	3 North	7:20	7:27	1800	6000
8/1/18	*	Black Cart	7:30	7:40	1500	3600
8/1/18	3 South	3 South	7:30	7:47	1800	7000
8/1/18	3 North	3 North	7:20	9:34	1800	6000
8/1/18	*	Black Cart	7:30	9:38	1200	3600
8/1/18	3 South	3 South	7:30	9:39	2100	6000
8/1/18	3 North	3 North	7:20	11:34	1500	4800
8/1/18	*	Black Cart	7:30	11:37	1200	4800
8/1/18	3 South	3 South	7:30	11:39	1500	6000
8/1/18	3 North	3 North	7:20	13:30	1500	6000
8/1/18	—	Black Cart	7:30	13:38	1200	3600
8/1/18	3 South	3 South	7:30	13:35	1500	6000

***indicates locations that were not known; — indicates samples with no hydrogen peroxide measurements because of limited supply of reagents in the hydrogen peroxide test kit; ppm = parts per million.**

Table A2. Odds ratios** for acute, cross-shift symptoms and age, gender, smoking status, allergic status, sensitizer and irritant containing product use during an employee's shift, and total stress, July–August 2018.

Health Outcome	Variable	OR	95% Lower Confidence Limit	95% Upper Confidence Limit
Nasal irritation	Age	0.99	0.94	1.04
	Gender	0.94	0.23	3.96
	Smoking Status	2.03	0.53	9.29
	Allergic Status	0.40	0.12	1.26
	Sensitizer and irritant use during shift	**2.00**	**1.02**	**4.22**
	Total Stress	**1.45**	**1.11**	**2.01**
Sneeze	Age	0.99	0.94	1.05
	Gender	0.40	0.07	2.08
	Smoking Status	**7.88**	**1.10**	**171.36**
	Allergic Status	**6.47**	**1.01**	**127.68**
	Sensitizer and irritant use during shift	**3.33**	**1.44**	**9.15**
	Total Stress	1.15	0.82	1.68
Throat irritation	Age	1.00	0.96	1.06
	Gender	1.19	0.30	5.42
	Smoking Status	2.49	0.60	13.65
	Allergic Status	1.42	0.43	5.25
	Sensitizer and irritant use during shift	1.78	0.91	3.71
	Total Stress	**1.38**	**1.06**	**1.87**
Eye irritation	Age	1.04	0.99	1.09
	Gender	0.52	0.15	1.81
	Smoking Status	1.02	0.30	3.59
	Allergic Status	1.61	0.56	4.90
	Sensitizer and irritant use during shift	1.62	0.88	3.15
	Total Stress	1.22	0.96	1.60
Cough	Age	1.00	0.94	1.06
	Gender	0.40	0.07	2.32
	Smoking Status	3.54	0.53	72.28
	Allergic Status	0.89	0.19	4.76
	Sensitizer and irritant use during shift	1.63	0.69	4.11
	Total Stress	1.00	0.72	1.40
Wheeze	Age	1.04	0.96	1.14
	Gender	1.16	0.17	11.79
	Smoking Status	0.44	0.08	2.83
	Allergic Status	0.44	0.09	2.17
	Sensitizer and irritant use during shift	0.89	0.31	2.48
	Total Stress	0.97	0.64	1.43
Shortness of breath	Age	0.98	0.92	1.04
	Gender	1.84	0.40	10.71
	Smoking Status	0.60	0.14	2.83
	Allergic Status	0.43	0.12	1.53
	Sensitizer and irritant use during shift	0.97	0.44	2.14
	Total Stress	**1.38**	**1.03**	**1.92**
Difficulty breathing	Age	0.95	0.86	1.03
	Gender	0.89	0.07	23.43
	Smoking Status	0.23	0.02	2.38
	Allergic Status	0.31	0.03	3.01
	Sensitizer and irritant use during shift	**4.25**	**1.06**	**24.38**
	Total Stress	0.99	0.58	1.64

Exposures that were significantly associated with work-related acute symptoms are noted in bold.
**** An odds ratio greater than one indicates a significant increase in work-related symptoms.**

Table A3. Odds ratios** for symptoms in the previous four weeks and age, gender, smoking status, allergic status, frequency of sensitizer and irritant containing product use in the previous four weeks, and total stress, July–August 2018.

Health Outcome	Variable	OR	95% Lower Confidence Limit	95% Upper Confidence Limit
Nasal irritation	Age	1.00	0.96	1.05
	Gender	2.77	0.80	11.39
	Smoking Status	1.76	0.51	6.64
	Allergic Status	0.76	0.27	2.17
	Sensitizer and irritant use in the previous four weeks	1.74	0.88	3.75
	Total Stress	1.07	0.85	1.38
Sneeze	Age	1.00	0.96	1.05
	Gender	0.80	0.23	2.88
	Smoking Status	**3.94**	**1.04**	**20.09**
	Allergic Status	0.99	0.34	2.94
	Sensitizer and irritant use in the previous four weeks	1.65	0.83	3.52
	Total Stress	1.08	0.85	1.37
Throat irritation	**Age**	**1.05**	**1.01**	**1.11**
	Gender	1.56	0.44	6.14
	Smoking Status	1.75	0.49	6.95
	Allergic Status	1.94	0.66	6.17
	Sensitizer and irritant use in the previous four weeks	1.15	0.57	2.35
	Total Stress	1.01	0.79	1.30
Eye irritation	Age	1.05	1.00	1.10
	Gender	1.81	0.52	6.78
	Smoking Status	2.13	0.60	8.28
	Allergic Status	2.60	0.89	8.17
	Sensitizer and irritant use in the previous four weeks	1.62	0.80	3.46
	Total Stress	1.02	0.80	1.31
Cough	Age	1.01	0.96	1.06
	Gender	0.43	0.10	1.75
	Smoking Status	**6.30**	**1.28**	**51.35**
	Allergic Status	0.96	0.28	3.49
	Sensitizer and irritant use in the previous four weeks	1.78	0.82	4.18
	Total Stress	**1.41**	**1.08**	**1.93**
Wheeze	**Age**	**1.06**	**1.01**	**1.13**
	Gender	0.93	0.23	4.29
	Smoking Status	2.31	0.56	12.57
	Allergic Status	1.33	0.39	5.07
	Sensitizer and irritant use in the previous four weeks	1.63	0.75	3.74
	Total Stress	1.16	0.88	1.56
Chest tightness	Age	1.06	0.99	1.14
	Gender	1.47	0.27	11.70
	Smoking Status	5.40	0.78	112.75
	Allergic Status	1.35	0.32	6.96
	Sensitizer and irritant use in the previous four weeks	1.31	0.52	3.32
	Total Stress	**1.48**	**1.06**	**2.17**

Table A3 (continued). Odds ratios** for symptoms in the previous four weeks and age, gender, smoking status, allergic status, frequency of sensitizer and irritant containing product use in the previous four weeks, and total stress, July–August 2018.

Shortness of breath	Age	0.97	0.92	1.02
	Gender	1.08	0.29	4.69
	Smoking Status	1.39	0.34	7.19
	Allergic Status	1.02	0.32	3.48
	Sensitizer and irritant use in the previous four weeks	0.89	0.40	1.93
	Total Stress	1.09	0.84	1.43
Difficulty breathing	Age	0.99	0.93	1.06
	Gender	0.73	0.14	4.50
	Smoking Status	0.77	0.15	4.67
	Allergic Status	0.61	0.12	3.21
	Sensitizer and irritant use in the previous four weeks	**3.12**	**1.10**	**10.87**
	Total Stress	1.34	0.97	1.92
Skin symptoms	Age	0.93	0.86	0.99
	Gender	1.12	0.25	5.53
	Smoking Status	0.91	0.18	5.32
	Allergic Status	0.89	0.23	3.75
	Sensitizer and irritant use in the previous four weeks	0.94	0.35	2.47
	Total Stress	**1.53**	**1.12**	**2.25**

Exposures that were significantly associated with work-related acute symptoms are noted in bold.
**** An odds ratio greater than one indicates a significant increase in work-related symptoms.**

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Availability of Report

Copies of this report have been sent to the employer and employees at the facility. The state health department and the Occupational Safety and Health Administration Regional Office have also received a copy. This report is not copyrighted and may be freely reproduced.

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