Field Survey Report

Exposure Assessment of Peracetic Acid-Based Disinfectant Chemicals in a Pediatric Hospital During Terminal Room Cleaning

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Abstract

Background

Peracetic acid (PAA) is a chemical with growing use as a disinfectant, sterilant, and biocide. PAA, in a mixture with hydrogen peroxide (HP) and acetic acid (AA), is used in a wide variety of industrial sectors including the food and beverage industry, feed, animal housing, hospitals and healthcare, agriculture, water purification, wastewater and sewage treatment, textile bleaching, pharmaceuticals, oil and gas, laundry, cosmetics, and the chemical industry. PAA is a strong oxidant with higher oxidizing potential than other biocides and is highly reactive on contact with organic material. PAA is corrosive to the skin, mucous membranes, and respiratory tract; and it is a sensory irritant. Although opportunities for employee exposures are increasing, there is little published information on workplace exposures or appropriate risk management approaches for working with mixtures of PAA, HP, and AA. Scientists from the National Institute for Occupational Safety and Health (NIOSH) are conducting a study to assess worker exposures to PAA-based disinfectants in healthcare, including hospitals. This report describes exposures to environmental services (EVS) staff at a children's hospital that uses a PAA-based disinfectant during terminal (or discharge) room and Giraffe™ incubator/isolette cleanings.

Assessment

NIOSH researchers conducted a site visit to assess worker exposures to the components of a PAA-based disinfectant during room cleaning tasks. EVS staff were monitored for exposure to PAA, HP and AA while conducting terminal room cleanings. These cleanings are performed when patients are discharged or moved to another room, and prior to the room being re-occupied. These cleaning procedures help reduce the likelihood of illness causing germs and bacteria from being spread from one patient to the next. During terminal room cleanings, EVS staff use the PAA-based disinfectant to clean and disinfect all low and high touch surfaces, including beds, bed rails, intravenous (IV) poles, tray tables, chairs, telephones, light switches, bathroom sinks and toilets as well as any other surface within the room.

We collected 17 task-based air samples for HP, PAA, and AA on EVS staff performing terminal room cleaning activities. Each task was comprised of a terminal room cleaning and sample duration ranging from 15 to 53 minutes. We also collected 2 samples during the cleaning of isolettes. We observed EVS staff while they performed their regular cleaning duties and noted task duration, cleaning product use, and use of any personal protective equipment.

Results

Acetic Acid: Worker personal air samples for AA ranged from 0.10 to 0.68 parts per million (ppm) during terminal room cleaning across the two days of sampling. The samples collected during the two isolettes cleanings ranged from 0.06 to 0.18 ppm.

NIOSH and the American Conference of Governmental Industrial Hygienists (ACGIH®) have a short-term exposure limit (STEL) of 15 ppm. The STEL is a 15-minute Time Weighted Average (TWA) exposure that should not be exceeded at any time during a workday.

Peracetic Acid: Worker personal air samples for PAA ranged from 0.04 to 0.51 ppm during terminal room cleaning across the two days of sampling. The samples collected during the two isolettes cleanings ranged from 0.02 to 0.08 ppm. ACGIH has a STEL of 0.4 ppm for PAA. The Occupational Safety and Health Administration (OSHA) and NIOSH do not have a STEL for PAA.

Hydrogen Peroxide: Worker personal air samples for HP ranged from 0.10 to 0.65 ppm during terminal room cleaning across the two days of sampling. The samples collected during the two isolettes cleanings ranged from 0.09 to 0.24 ppm. ACGIH, OSHA and NIOSH do not have a STEL for HP. ACGIH, OSHA and NIOSH have a full shift TWA limit of 1 ppm for HP, although it is not applicable to these short-term samples.

Conclusions and Recommendations

All measured levels of AA were below workplace safety limits for short term exposures. Two of the 19 short term sample results for PAA exceeded the ACGIH TLV-STEL of 0.40 ppm. There is no applicable short-term OEL for HP.

We observed varying levels of the disinfectant in the cloth buckets, including many with standing levels of disinfectant and rags which were dripping with the disinfectant when removed from the bucket for use. Some workers mentioned that the use of the chemicals caused skin irritation and upper respiratory symptoms like runny or stuffy nose.

We recommend that management ensure that employees understand potential hazards in the workplace and how to protect themselves. We also recommend that management ensure that employees have access and are informed of potential hazards and trained on the associated safe practices per the information found in the cleaning products' Safety Data Sheets (SDS). 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.

We recommend that management work with employees to reinforce training on the proper use of disinfectant and other products used in terminal room cleanings. This discussion should include the amount of product that should be used in buckets containing the wetted cloths and help address the thought that "more is better." Further, we recommend that management require employees to wear extended cuff nitrile gloves or other compatible impervious gloves when using the disinfectant to minimize likelihood of skin exposure and irritation.

Introduction

Peracetic acid (PAA) is a chemical with growing use as a disinfectant, sterilant, and biocide. PAA, in a mixture with hydrogen peroxide (HP) and acetic acid (AA), is used in a wide variety of industrial sectors including the food and beverage industry, feed, animal housing, hospitals and healthcare, agriculture, water purification, wastewater and sewage treatment, textile bleaching, pharmaceuticals, oil and gas, laundry, cosmetics, and the chemical industry [ECETOC 2001]. PAA is a strong oxidant with higher oxidizing potential than other biocides and is highly reactive on contact with organic material [National Research Council 2010]. PAA is corrosive to the skin, mucous membranes, and respiratory tract; and it is a sensory irritant [National Research Council 2010]. Although opportunities for employee exposures are increasing, there is little published information on exposures to workers using disinfectant chemical mixtures of PAA, HP, and AA.

PAA is considered to be a stronger sensory irritant than AA or HP [National Research Council 2010]. Asthma associated with exposure to PAA mixtures in healthcare workers has been reported [Cristofari-Marquand et al. 2007]. PAA is a strong oxidizer and oxidizes cell proteins and enzyme systems. The toxicity has been reviewed by Pechacek et al. [2015] and the primary target system is the respiratory tract, with only limited evidence for any systemic toxicity. Thus, sensory irritation is the most sensitive health endpoint and serves as the point-of-departure for derivation of health-based occupational exposure limits (OELs) [ACGIH 2019].

On March 27 and 28, 2024, National Institute for Occupational Safety and Health (NIOSH) researchers performed task-based air sampling and collected air samples on employees as they were conducting terminal cleaning in rooms throughout the hospital. We previously mailed a letter with interim air sampling results and preliminary recommendations on protecting workers from disinfectant chemical exposure. We observed Environmental Services Staff (EVS) staff while they performed their cleaning duties and noted task duration, cleaning product use and duration. In this report, we summarize the results from our exposure assessment. Additionally, we provide recommendations to help protect the employee health. The overall objective of this project is to assess exposures to PAA-based disinfectants in a variety of workplaces, focusing on food manufacturing and health care.

Process Description

Process Description

This site is a hospital that has over 300 beds and is focused on pediatrics and obstetrics and provides comprehensive services in key obstetric and pediatric areas, including brain & behavior, cancer, heart, pregnancy & newborn, pulmonary and transplant. The PAA-based product containing HP, PAA and AA is 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.

Study participants were sampled and observed while conducting terminal cleaning activities in rooms where patients have been moved or discharged to another area. Samples were collected from the breathing zone of each worker using a fishing vest to hold personal sampling pumps and real time monitors as described in the Methods section below. The goal of terminal cleaning is to thoroughly clean and disinfect surfaces before a patient is moved into the room. The disinfectant product was used as a wipe for cleaning all surfaces and was used at a concentration of 1,300 ppm of PAA and 6,300 ppm of HP. Wipes and mop heads were pre-wetted with the disinfectant and kept in containers (with lids) until use.

The terminal cleaning activities typically started with the removal of trash and collection of any used linens. The next task was to clean the bathroom, including the sink and toilet. EVS staff then used wetted wipes to wipe down low and high touch surfaces, including light switches, bed rails, door handles, all countertops, bedside tables, call bells, remote controls and IV poles. After all high touch surfaces had been cleaned by the EVS staff, they used wet mop pads to clean the floors and walls (in some instances).

In addition to monitoring terminal room cleanings, samples were taken during incubator/isolette cleanings. During these cleanings, the isolette is disassembled and the parts are either soaked in the disinfectant for 10 minutes before being dried with a towel or wiped down with disinfectant-wetted towels and dried before being reassembled. The personal samples collected on the workers in this study represent the exposures during the full terminal cleaning tasks for one room or one isolette

Occupational Exposure Limits and Health Effects

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH investigators use regulatory and recommended Occupational Exposure Limits (OELs) when evaluating chemical, physical, and biological agents in the workplace. Generally, OELs suggest levels of exposure to which most workers may be exposed up to 8-10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects even though their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the exposure limit. Combined effects are often not considered in the OEL. Also, some substances are absorbed by direct contact with the skin and mucous membranes, thus increasing the overall exposure. Finally, OELs may change over the years as new information on the toxic effects of an agent becomes available.

Most OELs are expressed as a Time Weighted Average (TWA) exposure. A TWA exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have a recommended Short-Term Exposure Limit (STEL) or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short-term.

In the U.S., OELs have been established by Federal agencies, professional organizations, state and local governments, and other entities. The U.S. Department of Labor Occupational Safety and Health Administration (OSHA) (Permissible Exposure Limits (PELs) (1910.1000 TABLE Z-1 - TABLE Z-1 Limits for Air Contaminants | Occupational Safety and Health Administration (osha.gov)) are OELs that are legally enforceable in covered workplaces under the Occupational Safety and Health Act. NIOSH Recommended Exposure Limits (RELs) are based on a critical review of the scientific and technical information available on the prevalence of health effects, the existence of safety and health risks, and the adequacy of methods to identify and control hazards [NIOSH 1992]. They have been developed using a weight of evidence approach and formal peer review process. Other OELs that are commonly used and cited in the U.S. include the Threshold Limit Values (TLVs®) recommended by the American Conference of Governmental Industrial Hygienist (ACGIH®), a professional organization [ACGIH 2024]. ACGIH® TLVs are considered voluntary guidelines for use by industrial hygienists and others trained in this discipline "to assist in the control of health hazards".

OSHA requires an employer to furnish employees a place of employment that is free from recognized hazards that are causing or are likely to cause death or serious physical harm [OSH Act of 1970 | Occupational Safety and Health Administration]. Thus, employers are required to comply with OSHA PELs. Some hazardous agents do not have PELs, however, and for others, the PELs do not reflect the most current health-based information. Thus, NIOSH investigators encourage employers to consider the other OELs in making risk assessment and risk management decisions to best protect the health of their employees. NIOSH investigators also encourage the use of the traditional hierarchy of controls approach to eliminating or minimizing identified workplace hazards. This includes, in preferential order, the use of: (1) elimination of the hazardous agent, (2) substitution of the hazardous agent, (3) engineering controls (e.g., local exhaust ventilation, process enclosure, dilution ventilation) (4) administrative controls (e.g., limiting time of exposure, employee training, work practice changes, medical surveillance), and (5) personal protective equipment (PPE) (e.g., respiratory protection, gloves, eye protection, hearing protection).

PAA/AA/HP Exposure Limits

Peracetic Acid (PAA)

There is only one set of U.S. OELs for PAA. ACGIH® published a limit of 0.4 parts per million (ppm, inhalable fraction and vapor) as a 15-minute TLV-STEL in 2014 on

the basis of irritation of eyes, skin and the upper respiratory tract [ACGIH 2019]. There is no OSHA PEL or NIOSH REL.

The California Division of Occupational Safety and Health (Cal/OSHA) Health Effects Advisory Committee (HEAC) recommended a PEL for PAA of 0.20 ppm (8-hr time-weighted average) and a 0.4 ppm 15-min STEL in December 2017 [Cal/OSHA 2017]. The recommendation has not been adopted but will be considered by the California Occupational Safety and Health Standards Board.

The Canadian Occupational Health Clinics for Ontario Workers has proposed a STEL of 0.2 ppm to the Canadian Ministry of Labour [Occupational Health Clinics for Ontario Workers 2016]. There are no current Canadian PAA OELs. There are no European Chemicals Agency recommended occupational exposure guidelines for PAA.

Pechacek et al. [2015] suggested an 8-hour PAA vapor TWA OEL ranging from 0.36 to 0.51 milligrams per cubic meter of air (mg/m^3) (0.1–0.2 ppm) and STEL OEL ranging from 1.2 to 1.7 mg/m^3 (0.4–0.5 ppm) based on toxicity data. They note that the PAA odor threshold is approximately 0.16 mg/m^3 or 0.05 ppm.

Acetic Acid (AA)

AA is used in many industrial processes and in the manufacture of vitamins, antibiotics, and as a food additive [Virginia Department of Health 2016]. Most types of vinegar are typically 4%–6% acetic acid. AA has a reported odor threshold of 24 ppm. AA solution contact with eyes and skin can cause eye damage and skin irritation. Dilute AA solutions have a low vapor pressure, which results in low inhalation exposures [ACGIH 2019]. NIOSH and OSHA have established OELs of 10 ppm as an 8-hour TWA [NIOSH 2010]. ACGIH has established a TLV-TWA of 10 ppm and a TLV-STEL of 15 ppm for AA [ACGIH 2024].

Hydrogen Peroxide (HP)

HP is a colorless liquid with a slightly sharp odor. HP can cause irritation to the eyes, nose, skin, and throat. HP is a common oxidizing agent used for bleaching or deodorizing textiles, wood pulp, hair, fur, and is used in the treatment of water and sewage [ACGIH 2019]. The OELs for HP are based on reducing the likelihood of irritation of the eyes, skin, mucous membranes, and respiratory tract. NIOSH, OSHA, and ACGIH have established OELs of 1 ppm for HP, as 8-hour TWAs [ACGIH 2024; NIOSH 2010].

Methods: PAA/AA/HP Sampling

We collected 19 personal air samples from twelve participating EVS staff members over 2 days of sampling (note that only seven participating members were sampled

on the 2nd day based on their availability and cleaning schedule). 17 samples were collected during terminal room cleanings and 2 were collected during the cleaning of an isolette. We measured the components of the PAA-based disinfectant, including AA, PAA, and HP on workers performing terminal room cleanings.

Acetic Acid

Samples were collected and analyzed using OSHA Method PV2119 [OSHA 2023] with a nominal sampling airflow rate of 1.0 liter of air per minute (L/min). Sampling was conducted using SKC AirChek TOUCH air sampling pumps (SKC Inc., Eighty Four, PA) calibrated at 1.0 L/min with glass sampling tubes (in tube covers) containing coconut shell charcoal (SKC# 226-01) attached with Tygon® tubing. The personal sampling pumps were pre and post calibrated using a National Institute of Standards and Technology (NIST) traceable calibrator (chek-mate®, SKC Inc. Eighty Four, PA).

Hydrogen Peroxide (HP) and Peracetic Acid (PAA)

We collected short-term task-based air samples for HP and PAA on each participating EVS staff member during 2 days of sampling. We collected samples simultaneously using both a treated silica gel tube (SKC#226-199-UC) and a 25-millimeter cassette with treated filters (SKC#225-9030) in-line with a nominal sampling airflow rate of 1.0 L/min. Samples were analyzed using an in-house method from the NIOSH contract laboratory based on the Hecht et al. method [Hecht et al. 2004]. This method allows for the simultaneous collection of PAA and HP, while at the same time assuring that HP does not interfere with the PAA sample.

This method requires two quartz filters coated with titanium oxysulfate hydrate preloaded in a 25-mm two-piece polystyrene cassette (with no support pad) to collect hydrogen peroxide placed upstream in series with a silica gel tube coated with methyl p-tolylsulfoxide with two glass wool separators to collect PAA. The filter and the silica gel tube were connected using a small piece of Tygon® tubing. Sample media was stored and transported to the site in a freezer prior to sampling. Following sampling, the cassettes for hydrogen peroxide samples were wrapped in foil to prevent degradation from exposure to light and returned to a freezer prior to shipping.

Samples were collected using SKC AirChek TOUCH air sampling pumps, which can maintain a constant flow at 1.0 L/min for the duration of the sample even at high backpressures. The pumps were pre and post calibrated after each sample to account for any pump flow degradation using an airflow calibrator.

Results

These samples were taken over the full task which varied from 8 min to 37 min. Since these were not compliance samples, we did not limit them to a 15-minute sampling period, but still compare these short samples to the 15-minute TLV-STEL as a reference. Staff occasionally chose to also wear a surgical mask in addition to gloves as mentioned earlier when working with cleaning products in each room. Terminal room cleaning sample durations ranged from 15 min to 53 min (mean: 37 min). Incubator/isolette cleaning duration ranged from 38-58 min.

We observed varying levels of the disinfectant in the wetted cloth containers, including many with standing levels of the chemical and rags which were dripping with the disinfectant when removed from the bucket for use. Some workers mentioned that the use of the chemicals caused tearing of the eyes and upper respiratory symptoms like runny or stuffy nose.

Acetic Acid

Individual task-based air sample results for AA are presented in Table 1. The summary statistics are in Figure 1. Worker personal air samples for AA ranged from 0.10 to 0.68 ppm across the two days of sampling. All measured levels of acetic acid were below workplace safety limits for short term exposures. Table 2 lists the summary statistics for samples from terminal room cleaning.

Hydrogen Peroxide

Individual task-based air sample results for HP are presented in Table 1. The summary statistics are shown in Figure 1. Worker personal air samples for HP ranged from 0.10 to 0.65 ppm across the two days of sampling. Table 2 lists the summary statistics for samples from terminal room cleaning.

Peracetic Acid

Individual task-based air sample results for PAA are presented in Table 1. The summary statistics are shown in Table 2 and in Figure 1. Worker personal air samples for PAA ranged from 0.02 to 0.51 ppm across the two days of sampling. Two of the 16 (12.5%) short term sample results for PAA exceeded the ACGIH TLV-STEL of 0.40 ppm. Table 2 also lists the summary statistics for samples from terminal room cleaning.

Temperature and Relative Humidity

Temperatures ranged from 65°F–80°F (Mean:71°F) and relative humidity ranged from 37%–56% (Mean:46%) on Day 1; temperatures ranged from 64°F–82°F (Mean:68°F) and relative humidity ranged from 33%–52% (Mean:43%) on Day 2.

Table 1. Summary of Air sampling data for Acetic Acid, Peracetic Acid and Hydrogen Peroxide

Date	Sample duration (minutes)	Acetic Acid (ppm)*	Peracetic acid (ppm)**	Hydrogen peroxide (ppm)†
3/27/2024	44	0.54	0.25	0.59
	36	0.56	0.35	0.64
	41	0.34	0.19	0.27
	45	0.35	0.18	0.39
	38	0.06	0.02	0.09
	46	0.48	0.27	0.38
	29	0.36	0.28	0.40
	32	0.43	0.21	0.39
	19	0.54	0.39	0.53
	53	0.30	0.18	0.30
	49	0.52	**0.51**	0.65
	15	0.34	0.28	0.35
3/28/2024	58	0.18	0.08	0.24
	19	0.68	**0.41**	0.57
	35	0.10	0.04	0.10
	10	0.69	**-**	-
	50	0.53	0.25	0.55
	34	0.50	0.30	0.47
	34	0.56	0.19	0.47

Yellow highlighted concentrations are above the applicable STEL.

The two sets of data highlighted in green were from isolette cleaning, and the other data were from terminal room cleaning.

Note: Hydrogen peroxide and peracetic acid data from one sample on 3/28/2024 are not presented in the table as the sampling pump stopped early during the task.

* The minimum detectable concentrations ranged from 0.006 to 0.022 ppm. The minimum quantifiable concentrations ranged from 0.020 to 0.076 ppm.

** The minimum detectable concentrations ranged from 0.002 to 0.010 ppm. The minimum quantifiable concentrations ranged from 0.005 to 0.027 ppm.

† The minimum detectable concentrations ranged from 0.012 to 0.072 ppm. The minimum quantifiable concentrations ranged from 0.057 to 0.333 ppm.

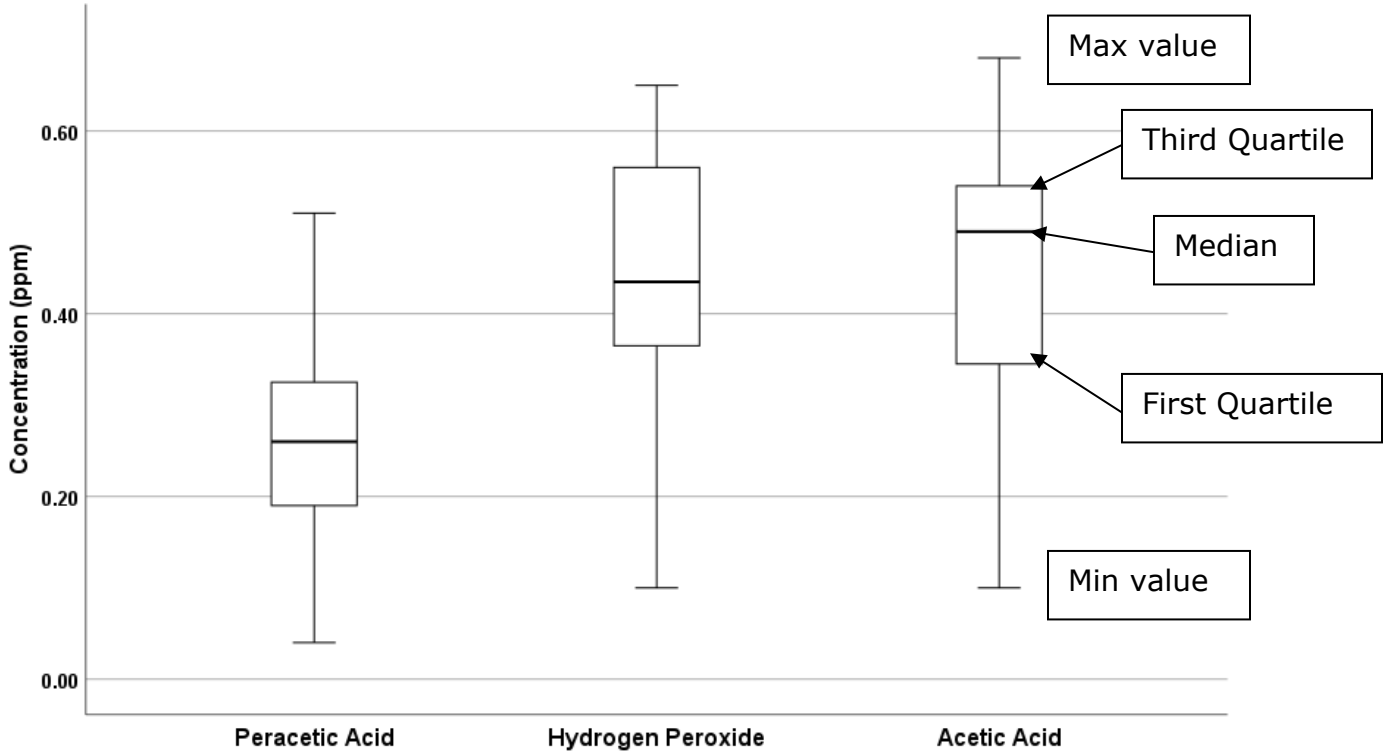
Table 2. Summary of air sample results for acetic acid, hydrogen peroxide and peracetic acid (terminal room cleaning samples).

Chemical	Number of samples	Mean Concentration (ppm)	Std Dev	min	max
Acetic acid	17	0.45	0.14	0.10	0.68
Hydrogen peroxide	16	0.44	0.15	0.10	0.65
Peracetic acid	16	0.27	0.11	0.04	0.51

ppm = parts per million; std dev = standard deviation; min = minimum concentration; max = maximum concentration

Note: One sample was removed from the PAA/HP dataset because the sample pump stopped early during the task.

Figure 1. Boxplot of air sample data showing distribution of concentrations of peracetic acid, hydrogen peroxide, and acetic acid.



Note: The upper and lower hash marks are the maximum and minimum values from the dataset. The midpoint line in the box is the median concentration value. The upper and lower line of the box are the upper and lower quartile-representing the points at which 25% and 75% of the concentrations fall below.

ACGIH® has a Short-Term Exposure Limit (STEL) of 0.4 ppm for peracetic acid.

There is no applicable STEL for hydrogen peroxide.

NIOSH and ACGIH® have a STEL of 15 ppm for acetic acid.

ppm = parts per million

Discussion

All measured levels of AA were below the OELs for short term exposures (15 ppm for both NIOSH and ACGIH TLV-STEL). The AA concentration from terminal room cleaning has an average of 0.45 ppm with a range from 0.10-0.68 ppm; and the AA concentration from isolette cleaning was even lower. These concentrations are two

orders of magnitude below the applicable STEL and unlikely to result in exposures above the STEL unless there is a change in process (e.g., disinfectant with higher AA concentration adopted, change to cleaning processes or amount of disinfectant used, etc.). The task-based mean exposure concentration for HP from terminal room cleaning was 0.44 ppm with a range from 0.10-0.65 ppm. Again, the HP concentration from isolette cleaning was even lower. ACGIH, OSHA and NIOSH do not have a STEL for HP. ACGIH, OSHA and NIOSH have a full shift time weighted average limit of 1 ppm for HP, although it is not applicable to these short-term samples.

Two of the 16 task-based sample results for PAA from terminal room cleaning exceeded the ACGIH TLV-STEL of 0.40 parts per million. The task-based mean exposure concentration for PAA from terminal room cleaning was 0.27 ppm with a range from 0.04-0.51 ppm, while the PAA concentration from isolette cleaning was much lower (0.02-0.08 ppm).

Because of the difficulty of measuring PAA in air, very little data are available in the published literature. In 2004, Hecht et al. published an article on the development of their analytical method for simultaneous measurement of PAA and HP in air. The method was validated by taking 144 measurements in mineral water factories and hospital dispensaries [Hecht et al. 2004]. This method was also used to measure exposures during equipment sterilization operations in a hospital. Dugheri et al. [2018] used multiple personal sampling methods, including the Hecht et al. [2004] method and a ChemDAQ direct-reading instrument, to measure exposures to PAA in a calibrated test chamber and in many workplace settings including beverage processing, wastewater treatment and hospital processes. The different sampling methods showed good agreement when evaluated in a controlled test chamber and in the various workplaces [Dugheri et al. 2018].

NIOSH researchers conducted a health and exposure assessment at a hospital where a PAA-based disinfectant/cleaner was used as the primary cleaner on hospital surfaces [Blackley et al. 2023]. The 56 personal and mobile (researchers followed employees while they performed cleaning duties and placed the samplers near cleaning staff during the tasks) air samples were collected for HP, PAA, and AA on participants while they performed their regular cleaning duties. Additional area samples were collected for HP (n = 28), PAA (n = 28), and AA (n = 70) in multiple hospital locations where cleaning was performed, and a post-shift survey was administered to assess eye, skin, and upper and lower airway symptoms that occurred cross-shift or in the previous 4 weeks. Full-shift exposure levels for HP (range: <3–559 parts per billion (ppb)), PAA (range:<0.2–8 ppb), and AA (range: <5–915 ppb) were all below U.S. OELs. However, they observed positive associations ($p < 0.05$) between shift, departmental average, and departmental 95th percentile exposures to HP, PAA, and AA vapors, and work-related acute (cross-shift) and chronic (previous 4 weeks) eye, upper airway, and lower airway symptoms.

Dalton et al. conducted chamber studies to assess personal exposure to PAA, AA, and HP during terminal cleaning activities in a mock patient room [Dalton et al. 2023]. PAA-based disinfectant solution (3 ounces OxyCide™ concentrate per gallon of water; Ecolab, Minneapolis, MN) which contained 0.13% PAA, 0.16% AA, and 0.64% HP was used for these trials. Participant exposures to PAA, AA, and HP were measured in the volunteer's breathing zone and pre-wetted microfiber cloths were used to wipe for 20 minutes to disinfect a set of high-touch nonporous surfaces found in mock patient room or bathroom spaces. In addition, 15 objective measures of tissue injury or inflammation and 4 subjective odor or irritation scores were assessed. Mean exposures to PAA were 66.2 ppb (SD:23.1), HP were 286.6 ppb (SD:120.9), and AA were 387 ppb (SD:148). Subjective irritation scores for the disinfectant trials (PAA/AA/HP) were elevated for odor and nose irritation, with lower scores for eye and throat irritation. None of the volunteers exhibited increases in objective measures of eye and respiratory tract inflammation (e.g., eye redness, vascularity, nasal nitric oxides or cytokines).

Conclusions

Overall, exposures to PAA, HP, and AA were mostly below OELs. However, there were two PAA exposures above the ACGIH STEL during our task-based terminal room cleaning personal sampling. Airborne exposures to disinfectant chemicals during terminal room cleaning can be the result of several factors, including room volume and ventilation, furniture and equipment in the room (more equipment = more surfaces to disinfect with product), product type and chemical ingredient concentration and work practices (using more than required amount of disinfectant). Exposures to PAA in industry have not been well documented due to the difficulty with the sampling methods (high sample backpressure, complicated sample storage and transportation). This report provides valuable information about exposures to PAA, HP, and AA among EVS staff at one hospital during terminal room cleaning tasks. Although most exposures were below applicable OELs, it is important to look for ways to minimize exposures and monitor for any symptoms or health effects among EVS staff.

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 [Rutala and Weber 2024]. 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, U.S. Environmental Protection Agency (EPA) regulations, and OSHA requirements and identify areas and tasks where there is the potential for exposure as well as how to deal with inadvertent spills.

Additional information is provided in the Recommendations section below.

Recommendations

Controlling exposures to occupational hazards is the fundamental method of protecting workers. Traditionally, a hierarchy of controls has been used as a means of determining how to implement feasible and effective controls. One representation of the hierarchy of controls can be summarized as follows:

- Elimination
- Substitution
- Engineering Controls (e.g., ventilation)
- Administrative Controls (e.g., reduced work schedules)
- Personal Protective Equipment (PPE, e.g., respirators)

The idea behind this hierarchy is that the control methods at the top of the list are potentially more effective, protective, and economical (in the long run) than those at the bottom. Following the hierarchy normally leads to the implementation of inherently safer systems, ones where the risk of illness or injury has been substantially reduced.

Elimination or Substitution

A primary approach to minimizing exposure risk is to eliminate hazardous materials or processes. Disinfectants are an important part of reducing healthcare-acquired infections. However, the choice to use disinfectants in specific areas of the hospital should be prudent and reflect the level of risk of a healthcare-acquired infection. HICPAC provides recommendations for when and where sterilization with sporicides versus disinfection with high- and low-level disinfectants should occur in healthcare facilities [Rutala and Weber 2024]. Exposure to vapors containing HP, PAA, and AA could be reduced by substituting products 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 (e.g., 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. Engineering control recommendations include:

1. Ensure the dispensers for the disinfectant product containing HP, PAA, and AA are calibrated to effectively dilute the product to manufacturer's recommended concentrations of PAA.

2. Ensure all heating, ventilation, and air-conditioning systems are functioning well and meet all applicable ASHRAE standards for ventilation of health care facilities [ANSI/ASHRAE/ASHE 2021].

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. Administrative control recommendations include:

1. 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 updated 2008 HICPAC Guideline recommends each worker be informed of the possible health effect(s) of his or her exposure to chemicals [Rutala and Weber 2024]. 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, EPA regulations, and OSHA requirements and identify areas and tasks where there is the potential for exposure. These trainings should be offered in the preferred language of the employee.

2. Ensure that EVS staff know the proper amount of product to wetted cloth ratio and that the cloths should be damp but not dripping. Excess disinfectant may possibly result in unnecessary exposure to PAA/HP/AA during product use. Reinforce in training that "more is better" does not apply to disinfectant concentrations or applications.

3. Implement a 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 disinfectants and sterilants. These reports should be reviewed regularly, and the facility should implement controls to prevent exposures.

4. A team approach should be used when introducing a new cleaning product or system. A committee representing all appropriate parties (e.g., EVS staff, patient care staff, infection preventionists, occupational health and safety representatives) should be convened when new cleaners and 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

interested parties, 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. Personal protective equipment recommendations include:

1. Require employees to wear extended cuff nitrile gloves or other compatible impervious gloves when using the disinfectant 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.

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