Evaluation of Peracetic Acid Exposure and Symptoms among Employees at a Beverage Manufacturing Facility

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Program Description

The National Institute for Occupational Safety and Health (NIOSH) Health Hazard Evaluation Program investigates possible health hazards in the workplace under the authority of the Occupational Safety and Health Act of 1970 [29 USC 669a(6)]. The Health Hazard Evaluation Program also provides, upon request, technical assistance to federal, state, and local agencies to investigate occupational health hazards and to prevent occupational disease or injury. Regulations guiding the Program can be found in Title 42, Code of Federal Regulations, Part 85; Requests for Health Hazard Evaluations [42 CFR Part 85].

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Availability of Report

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

Recommended Citation

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Introduction

Request

A union representing employees at a beverage processing plant requested a health hazard evaluation for employees working in two departments. They were concerned with employee exposures to peracetic acid (PAA), which is used to sanitize containers prior to filling them with beverages. PAA readily breaks down into hydrogen peroxide and acetic acid, so we also included these chemicals in the evaluation.

Workplace

The beverage plant was built in the 1940's. While the initial facility remains, several additions have been completed since its construction. At the time of our visit, the facility covered several acres. The evaluation focused on two departments, which were in separate parts of the facility. We will refer to these departments as Filler Operations (FO) and Carton Operations (CO). Employees worked in three shifts. FO employees worked on six different production lines to bottle beverages. Each production line included a sterilizer, in which PAA was used to sterilize containers before they were filled. In the CO department, employees worked on a single production line to fill and package beverage cartons. PAA was previously used in a sterilizer in the department; however, at the time of our visit, PAA was not being used in CO.

To learn more about the workplace, go to Section A in the Supporting Technical Information

Our Approach

We visited the facility in July 2023 and again in July 2024. During our first visit, we met with management and union representatives to discuss PAA use and work processes and practices, conduct informal interviews with employees about their work and health and safety concerns, and request information about workplace policies and procedures. We used information from our initial visit to develop a plan for our second visit. During our second visit, we did the following:

- Collected air samples for PAA, acetic acid, and hydrogen peroxide.
- Measured PAA, temperature, and relative humidity with direct-reading instruments.
- Administered confidential questionnaires to employees.
- Observed work processes and work practices.

To learn more about our methods, go to Section B in the Supporting Technical Information

Our Key Findings

Detectable levels of peracetic acid and acetic acid were measured near peracetic acid sterilizer cabinets

- One employee was exposed to a PAA concentration above the American Conference of Governmental Industrial Hygienists (ACGIH®), threshold limit value (TLV®) short-term exposure limit (STEL) of 0.4 parts per million (ppm). The employee was exposed to an air concentration of 0.41 ppm over a 15-minute period.
- PAA area sample results, which cannot be directly compared to the TLV-STEL, ranged from non-detectable to 0.53 ppm.
- Employees would have negligible exposures to hydrogen peroxide and acetic acid when working near sterilizers, based on personal and area sample results.

Work-related symptoms, especially eye and nose irritation, were common among employees

- Approximately half of employees participating in the evaluation reported at least one work-related symptom consistent with PAA exposure during the prior four weeks.
- Approximately 40% of employees participating in the evaluation reported experiencing at least one work-related symptom during their previous shift.
- The most common symptoms were eye and nasal irritation. Employees also reported cough, wheeze, chest tightness, shortness of breath, or difficulty breathing, but these symptoms were less common.
- Measured PAA levels in air were not statistically associated with the prevalence of work-related symptoms.
- The prevalence of work-related symptoms was consistently highest among employees working on or around older sterilizers compared with newer sterilizers, although differences in the prevalence of symptoms between sterilizers were not statistically significant.
- Work-related eye and nasal irritation were more commonly reported by employees working third shift compared with other shifts.

Employee exposures to PAA could be reduced with improvements to workplace programs and procedures

- A lack of preventative maintenance had resulted in PAA leaks in various areas in the FO department.

- Employees exhibited a range of knowledge about how PAA control measures and facility policies, procedures, and personal protective equipment (PPE) use reduce PAA and other chemical exposures.
- Some PAA monitors displayed negative readings or abnormally high readings. There were no standard operating procedures available to guide employee or management actions based on the monitor readings.

To learn more about our results, go to Section B in the Supporting Technical Information

Our Recommendations

The potential benefits of improving workplace health and safety are:

↑ Improved worker health and well-being	↑ Enhanced image and reputation
↑ Better workplace morale	↑ Superior products, processes, and services
↑ Easier employee recruiting and retention	↑ Increased overall cost savings

The recommendations below are based on the findings of our evaluation. These recommendations are workplace-specific, based on the information available for the workplace evaluated, and are intended to improve this workplace's conditions. For each recommendation, we list a series of actions you can take to address the issue at your workplace. The actions at the beginning of each list are preferable to the ones listed later. The list order is based on a well-accepted approach called the "hierarchy of controls." The hierarchy of controls is a way of determining which actions will best control exposures. In most cases, the preferred approach is to eliminate hazards or to replace the hazard with something less hazardous (i.e., substitution). Installing engineering controls to isolate people from the hazard is the next step in the hierarchy. Until such controls are in place, or if they are not effective or practical, administrative controls and PPE might be needed. Read more about the hierarchy of controls on the NIOSH website.

We encourage the company to use a health and safety committee to discuss our recommendations and develop an action plan. Both employee representatives and management representatives should be included on the committee. Helpful guidance can be found in OSHA's Recommended Practices for Safety and Health Programs.

Recommendation 1: Reduce worker exposures to PAA

Why? PAA is a chemical used in a mixture with acetic acid and hydrogen peroxide in this facility. PAA can hurt the skin, mucous membranes (like your eyes and nose), and respiratory tract (mouth, nose, throat, and lungs). Little information has been published on how to manage risk when working with mixtures of PAA, acetic acid, and hydrogen peroxide.

While PAA concentrations measured during this evaluation were generally below applicable exposure limits, the type and prevalence of reported employee symptoms are consistent with those typically associated with PAA exposures. Improvements to engineering and administrative controls can reduce employee exposures to PAA and the occurrence of irritating symptoms.

How? At your workplace, we recommend these specific actions:

Create and implement a preventative maintenance program to prevent leaks and reduce potential employee exposures to PAA.

- Conduct routine inspections of the sterilizer cabinet to check for PAA leaks and corrosion of sterilizer components.
- Routinely replace sterilizer gaskets, piping, and plastic fixtures to prevent PAA leaks.
- Create and implement a ventilation system maintenance and filter-changeout schedule to ensure the heating, ventilation, and air-conditioning (HVAC) system is working properly and adequately removing PAA from the air.

Increase the airflow of the ventilation system to increase the capture of peracetic acid vapors.

- Consult with a qualified ventilation professional to determine if increasing the ventilation system's airflow will increase the capture of peracetic acid vapors. Increasing airflow too much may create turbulent airflow and decrease capture efficiency. Any changes to the ventilation system should be checked after the change to ensure that the system is working as designed.
- Assess the PAA capture system periodically to ensure the system is working as designed and appropriately reducing PAA concentrations.

Standardize employee training on PAA hazards and control measures.

- Ensure employees receive training about PAA and other chemicals used in the facility. Training should include information about what chemicals are present in the facility, what the symptoms or health effects are from exposure to those chemicals, and what control measures should be used to reduce exposures. Control measures discussed should follow the hierarchy of controls and include engineering and administrative controls with PPE use as a last measure to control exposures. More detail on this topic

can be found on NIOSH's website About Hierarchy of Controls and OSHA's Hazard Communication Standard.

- Ensure employees are aware of when and how to don (put on), doff (remove), and maintain PPE to effectively reduce exposures to PAA.

Develop standard operating procedures for PAA monitor placement and use.

- Standardize management and employee actions for when PAA monitors display abnormally high or negative readings.
- Reposition or redirect fans so they are not interfering with PAA monitors. If fans are permanent, consider moving the monitor to a location without a fan blowing directly on it. Monitors should be unobstructed, placed near worker positions and height (5–6 feet above the floor), and away from fans or blowers to ensure measurements displayed are as accurate as possible.
- Follow up with the PAA monitor manufacturer regarding issues with and questions about PAA monitors. Specifically, continue to discuss with the manufacturer abnormal readings (i.e., negative readings, elevated readings that are inconsistent with observation), and placement of monitors to improve accuracy and interpretation of the readings.

Continue to assess employee exposures to PAA, especially when working near sterilizers.

- Monitor worker PAA concentrations during tasks requiring the opening of the sterilization/filling enclosures to document exposures and develop appropriate mitigation approaches, if necessary.
- Reevaluate employee PAA exposures if there are any changes to the chemical concentration, exposure controls, or the amount used or how it's used.

Recommendation 2: Use employee reports of symptoms and health concerns to inform changes to control measures

Why? Understanding the occurrence of symptoms can provide useful information about how best to improve control measures. By monitoring and documenting where and when symptoms occur, management can better understand where exposures may be occurring and take action to reduce exposures. In addition, monitoring and documenting where and when symptoms occur may also allow management to evaluate how well control measures are working.

Although the company has multiple ways for employees to report health and safety concerns, improvements can be made to strengthen the company's ability to use these data to identify and evaluate exposure reduction interventions.

How? At your workplace, we recommend these specific actions:

Implement a reporting system for employees to report work-related symptoms, with the option to remain anonymous for employees who do not wish to be identified.

- Consider collecting information, including department, sterilizer, and shift worked, when employees report symptoms.
- Do not require employees to report detailed information that would allow them to be easily identified, if they would like to remain anonymous.
- Examine policies for reporting symptoms and other injuries or illnesses to identify barriers that might stop or discourage employees from reporting. Change policies and procedures to lessen issues that would keep employees from reporting symptoms, injuries, or illnesses.

Regularly analyze symptom reports to identify where interventions need to be improved or implemented.

- Identify patterns in the occurrence of symptoms. Stratify analysis to look at symptom reports during different periods and by department, sterilizer, shift, or other relevant work-related factors.
- Establish a regular schedule to review symptom reports in conjunction with employee and union representatives to identify departments, sterilizers, or shifts that need to be evaluated further. Ensure that the review protocols maintain privacy and confidentiality of private medical information.
- Use symptom reports to help evaluate how well interventions work in reducing employee symptoms after they are implemented.
- Regularly communicate with union representatives and employees about how symptom reports are used and what is being done to address concerns.

Encourage employees to report new, persistent, or worsening symptoms to their personal healthcare provider. Employees with symptoms can provide their personal healthcare provider with a copy of this report.

Encourage employees to seek care from a healthcare provider who is knowledgeable in occupational and environmental medicine, if medical concerns arise related to exposures at work.

- The American College of Occupational and Environmental Medicine and the Association of Occupational and Environmental Clinics maintain databases of providers to help locate an occupational medicine clinician in your geographic area.

Recommendation 3: Address other health and safety issues we identified during our evaluation

Why? A workplace can have multiple health hazards that cause worker illness or injury. Similar to the ones identified above, these hazards can potentially cause serious health symptoms, lower morale and quality of life for your employees, and possibly increased costs to your business. We saw the following potential issues at your workplace:

- Temperature and humidity variation in different areas of the facility existed based on time of day and sampling location. We measured temperatures as high as 91°F and humidity as high as 78% near employee work areas. It did not appear that the ventilation system was designed to regulate temperature or humidity within the facility. Therefore, heat stress is a concern, especially in the hotter and more humid times of year.
- Some chemical containers in the facility had labels that were tattered or difficult to read.

Although they were not the focus of our evaluation, these hazards could cause harm to your workers' health and safety and should be addressed.

How? At your workplace, we recommend these specific actions:

Reduce heat exposure in the production areas of the facility

- Consult with a qualified ventilation professional and discuss options to increase cooling airflow and regulate temperature and humidity in workspaces.
- Measure the air movement periodically to ensure the facility HVAC system is appropriately controlling indoor environmental quality.

Create and implement a heat stress prevention program

- A prevention program should include heat index measurements, a heat illness prevention plan, worker training, and engineering/administrative controls.
- Use information from the OSHA Heat Stress Guide. Also refer to CDC Workplace Recommendations on reducing heat exposures.

Ensure chemical totes and containers are appropriately labeled and that labels are in good condition

- Replace any chemical labels that are incorrect, torn or otherwise illegible.

Supporting Technical Information

Evaluation of Peracetic Acid Exposure and Symptoms among Employees at a Beverage Manufacturing Facility

HHE Report No. 2023-0033-3427

February 2026

Section A: Workplace Information

Employee Information

Number of employees at time of evaluation: 192

Length of shift: 8 hours

Union: Yes

Process Description

The beverage plant encompassed several buildings of varying sizes. Peracetic acid (PAA) is used as a sterilizing agent in two departments within the beverage plant, hereafter referred to as the Filler Operations (FO) and Carton Operations (CO) departments. At the time of our second visit, there were 129 employees working in FO and 63 in CO, staffing three shifts. Due to the seasonal nature of beverage production, the number of staff required at the plant fluctuated depending on need, with the largest number of staff required during harvest season.

A mixture of PAA, hydrogen peroxide, and acetic acid is brought into the facility in large totes. Two employees are responsible for transporting the totes from the staging area into the facility. There, a hose is connected to the totes and the PAA is pumped into the filler machine (located in the chemical room) for dilution, using acetic acid and hydrogen peroxide, to a target concentration of 22%. Once the PAA has reached the target concentration, it is transported through a system of pipes from the chemical room to PAA spray cabinets (also called sterilizers) on beverage production lines for use.

There were six FO production lines at the time of our visit, labelled by number. The CO department had one production line. The sterilizers in both departments were automated and enclosed to prevent outside contamination from entering the sterilizer and to reduce employee PAA exposures. At the time of our visit, PAA was not being used in the CO department sterilizer, although it had been used in the past. Containers of varying materials are first formed within the enclosure or fed into the production line where, in the FO department they are sanitized in the sterilizer using a PAA solution and then rinsed with clean water. Further down the production line, the containers are filled with a beverage, labelled, and packaged for shipment. At least one employee is posted at control panels near the sterilizers to monitor PAA levels and other system parameters. Employees are occasionally required to open the sterilizers for system maintenance or to clear a jam. The entire production line is periodically purged with a higher concentration of PAA to sanitize all components.

Section B: Methods, Results, and Discussion

Methods: Sterilizer Exposure Assessment

We collected personal and area samples for PAA and hydrogen peroxide, as well as area samples for acetic acid. We also measured temperature and humidity. We collected samples at each of the six sterilizers in the FO department across the three shifts. At the time of our visit, the production line in the CO department was not using PAA; therefore, we did not conduct sampling in the CO department.

PAA and Hydrogen Peroxide Personal Breathing Zone Samples

We collected 15-minute short-term personal breathing zone air samples for PAA and hydrogen peroxide simultaneously using a treated silica gel tube (SKC #226-199-UC) and a 25-millimeter cassette housing quartz filters treated with titanium oxysulfate hydrate (SKC #225-9030) in-line, calibrated to a nominal flow rate of 1.0 liter of air per minute. Employees participated voluntarily and were selected based on job, task or their work area's proximity to sterilizers. Each measurement represents one 15-minute sample. Some employees participated in consecutive samplings, depending on availability. Samples were analyzed using an in-house method from the NIOSH contract laboratory based on the Hecht et al. method [2004]. The Hecht et al. method may underestimate PAA concentrations in air when PAA is used as a spray. Despite this, the Hecht method is the standard method for measuring PAA concentrations in air.

PAA and Hydrogen Peroxide Area Samples

We also collected 15-minute short-term area samples for PAA and hydrogen peroxide using the Hecht et al. method [2004]. For these samples, we secured sampling pumps to tripods with the cassettes placed roughly 5 feet above the floor. We placed the tripods at the control panels nearest to the sterilizers where employees were posted near the production line.

PAA Direct Reading Instruments

Over 3 days, we also measured PAA for the entire shift at several sampling locations using ChemDAQ, Inc. SafeCide™ direct reading instruments (Pittsburgh, PA). The instruments logged measurements every 2 seconds. In a previous evaluation, we noted that the PAA monitors often start logging negative concentrations (up to -4.5 parts per million [ppm]) when initially turned on and for a short period before returning to zero [NIOSH 2024]. Conversations with the manufacturer did not provide an immediate solution other than allowing for the instrument to "warm-up" for a few minutes before collecting data. For this evaluation, we removed the initial negative "start-up" data until the concentrations logged were consistently at or above 0 ppm. However, a few negative values occurred even after removing these early "start-up" negative values.

Acetic Acid

We collected 4-hour area samples for acetic acid for each of the sterilizers across all three shifts. Samples were collected using a charcoal tube (SKC #226-01) at a nominal flow rate of 0.2 liters per minute and analyzed according to the Occupational Safety and Health Administration (OSHA) Method

PV2119 [OSHA 2025]. Sampling pumps were placed on the same tripods used to collect PAA and hydrogen peroxide samples.

Temperature and Humidity

We measured temperature and humidity using the Onset® HOBO® Pro V2 temperature and relative humidity data logger (Bourne, MA). We placed meters throughout the FO area near sterilizers and near filler machines. Measurements were recorded every 15 minutes during the workday.

Results: Sterilizer Exposure Assessment

PAA and Hydrogen Peroxide Personal Breathing Zone Air Samples

Short-term PAA personal air sampling results by shift and sterilizer can be found in Table C1. Overall, the average short-term employee PAA exposure was 0.14 ppm (range: 0.00 ppm–0.41 ppm) (n=46).

The distribution of short-term PAA personal breathing zone air samples varied by sterilizer (Figure B1). Most sample results were below the American Conference of Governmental Industrial Hygienists (ACGIH®) threshold limit value (TLV®) short-term exposure limit (STEL) of 0.4 ppm. One sample result for an employee working around sterilizer 2 exceeded the ACGIH TLV-STEL at 0.41 ppm. Employee exposures while working around sterilizers 5 and 6 were lower and less variable than employee exposures when working around other sterilizers.

The distribution of short-term PAA exposures were similar across the three shifts (Figure B2). The one result exceeding the ACGIH TLV-STEL occurred during first shift. It is important to note that the distributions shown for sterilizer 3 and second shift, are based on a small number of samples.

There were no employee exposures to hydrogen peroxide recorded above the limit of detection (LOD) of 1 microgram per meter cubed ($\mu g/m^3$) on any of the sterilizers.

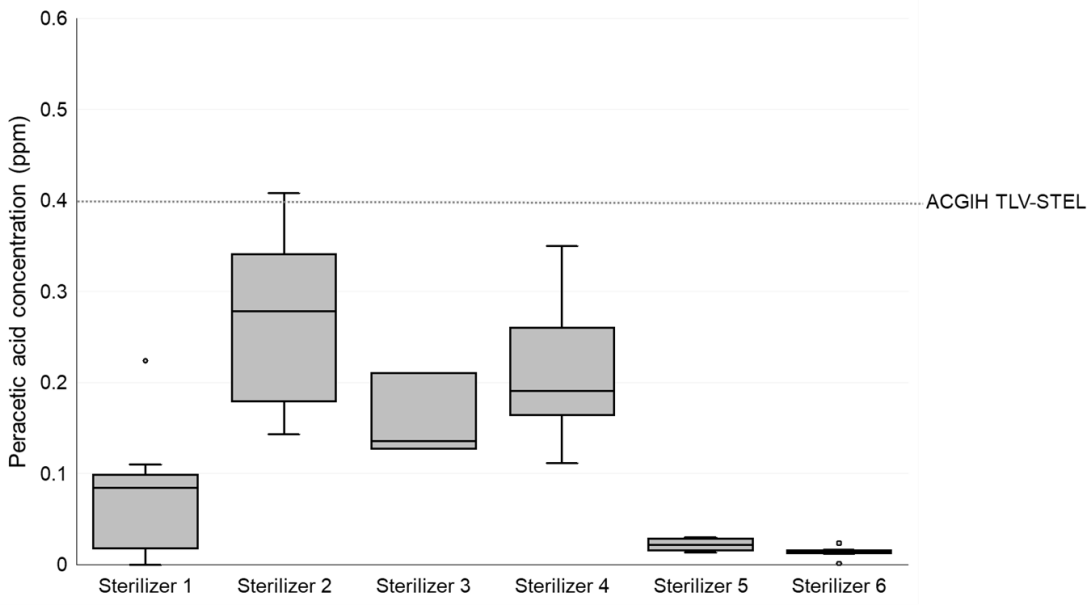

Figure B1. Box plots illustrating the distribution of 15-minute average PAA personal breathing zone air sample results by sterilizer. The box plots illustrate each quartile with the minimum shown as the line and hatch mark below the box, the first and third quartiles indicated by the shaded box, and the maximum 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 ACGIH TLV-STEL is indicated for reference at 0.4 ppm.

Note: ppm = parts per million, ACGIH = American Conference of Governmental Industrial Hygienists, TLV = threshold limit value, STEL = short-term exposure limit

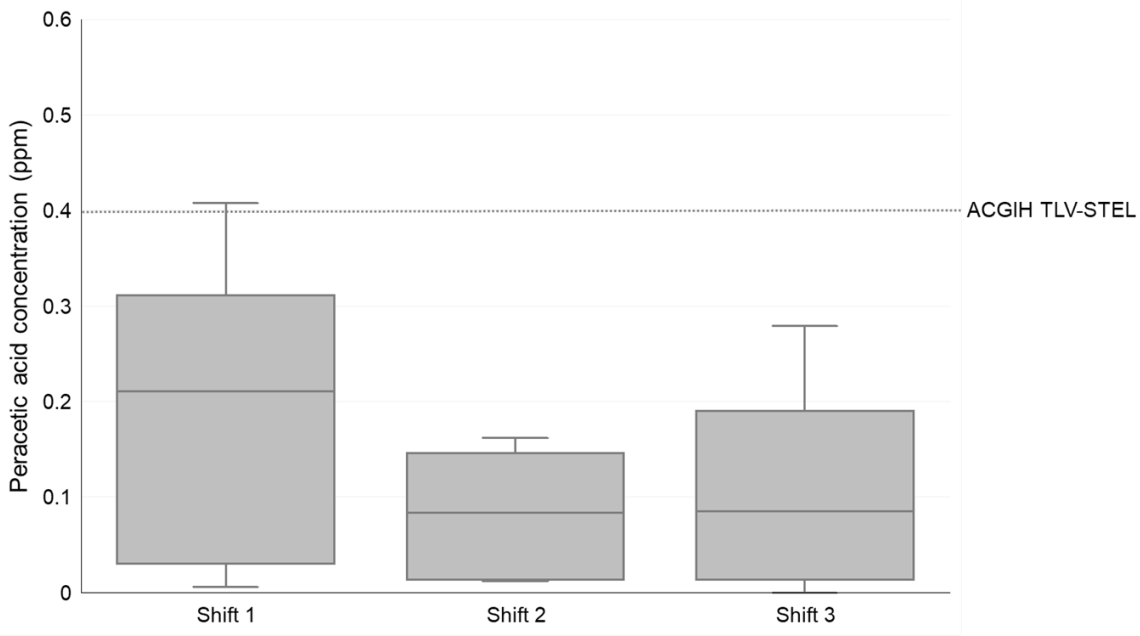

Figure B2. Box plots illustrating the distribution of 15-minute average PAA personal breathing zone air sample results by shift. The box plots illustrate each quartile with the minimum shown as the line and hatch mark below the box, the first and third quartiles indicated by the shaded box, and the maximum 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 ACGIH TLV-STEL is indicated for reference at 0.4 ppm.

Note: ppm = parts per million, ACGIH = American Conference of Governmental Industrial Hygienists, TLV = threshold limit value, STEL = short-term exposure limit

PAA and Hydrogen Peroxide Area Samples

Average PAA area sampling results can be found in Table C2. PAA area sampling results also averaged 0.14 ppm (range: 0.01 ppm–0.33 ppm) (n=110). Although area sampling results are not directly comparable to occupational exposure limits (OELs), we provide the OEL as a reference point.

Similar to the personal air sampling results, the distribution of area PAA air concentrations varied by sterilizer (Figure B3). Concentrations above the ACGIH TLV-STEL of 0.4 ppm were observed in areas around sterilizers 2 and 3. Around sterilizers 5 and 6 concentrations of PAA were lower and less variable during the sampling period compared with areas around other sterilizers. There were no measured hydrogen peroxide area sampling results recorded above the LOD of 1 μg/m^3 on any of the sterilizers.

We also found that the distribution of measured area airborne PAA sample concentrations were similar by shift (Figure B4). Concentrations above the ACGIH TLV-STEL of 0.4 ppm were observed during first and second shift.

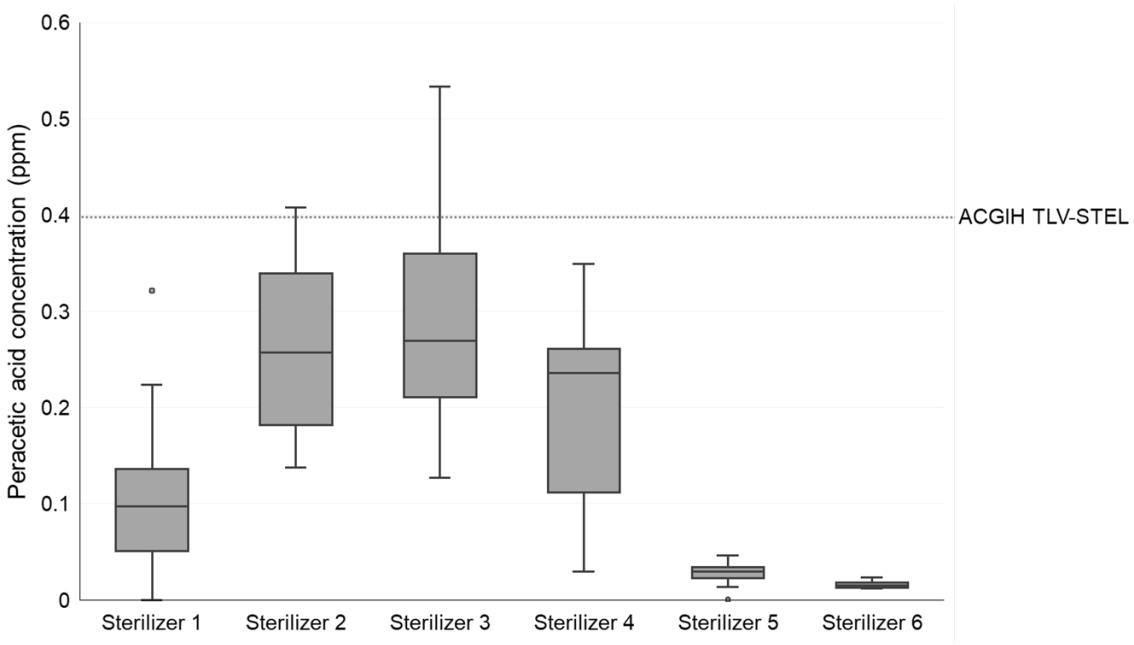

Figure B3. Box plots illustrating the distribution of 15-minute average PAA area air sample results by sterilizer. The box plots illustrate each quartile with the minimum shown as the line and hatch mark below the box, the first and third quartiles indicated by the shaded box, and the maximum indicated 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 ACGIH TLV-STEL is indicated for reference at 0.4 ppm.

Note: ppm = parts per million, ACGIH = American Conference of Governmental Industrial Hygienists, TLV = threshold limit value, STEL = short-term exposure limit

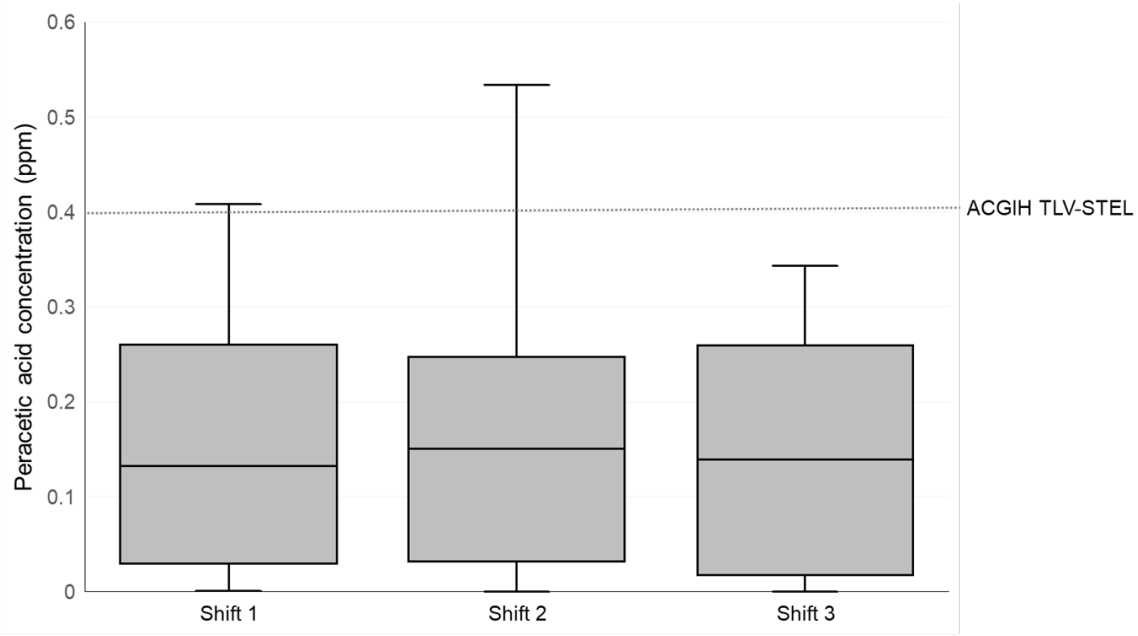

Figure B4. Box plots illustrating the distribution of 15-minute average PAA area air sample results by shift. The box plots illustrate each quartile with the minimum shown as the line and hatch mark below the box, the first and third quartiles indicated by the shaded box, and the maximum indicated by 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 ACGIH TLV-STEL is indicated for reference at 0.4 ppm.

Note: ppm = parts per million, ACGIH = American Conference of Governmental Industrial Hygienists, TLV = threshold limit value, STEL = short-term exposure limit

Average area PAA air concentrations by sterilizer and shift all remained below the ACGIH TLV-STEL (Figure B5). Areas near sterilizers 2, 3, and 4 had the highest average PAA air concentrations. Due to sample collection errors for sterilizer 4, the exact start times for these samples were not known but approximations were made to calculate concentration estimates based on average sample collection time of 15 minutes. Therefore, sterilizer 4 PAA air concentrations should be considered as approximate concentrations.

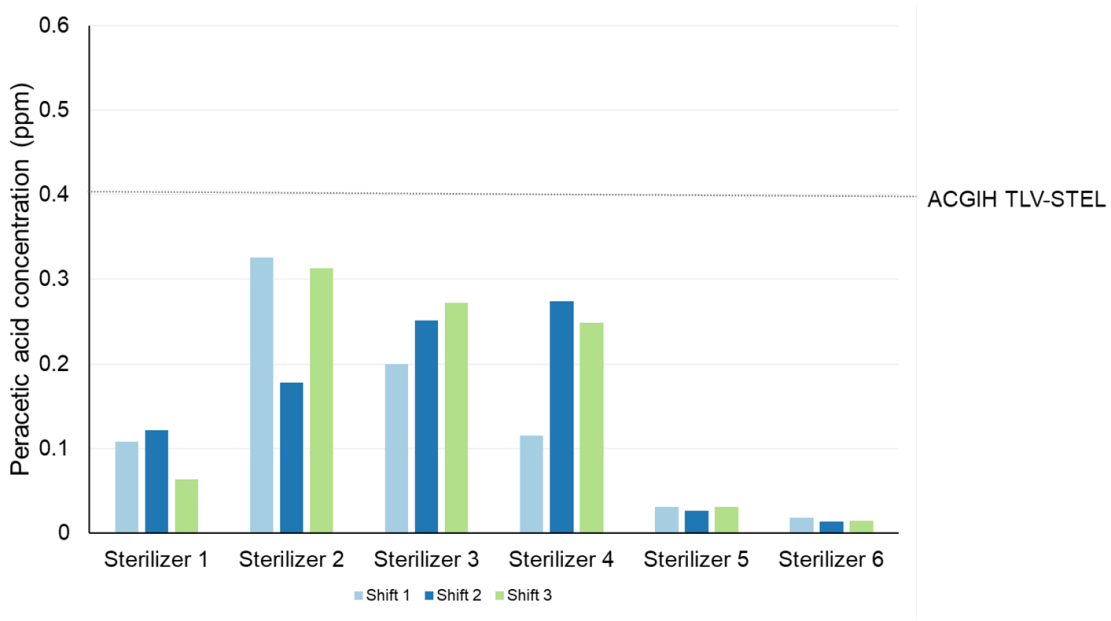

Figure B5. Average area PAA concentrations by sterilizer and shift. Note that, due to gaps in data collection, Sterilizer 4 concentrations for Shift 2 are approximate.

Note: ppm = parts per million

PAA Direct Reading Instruments

PAA concentrations recorded by direct reading instruments are presented in Table C3. Excluding the negative values, the average concentrations of PAA at each sterilizer sampling location ranged from 0.01 ppm to 0.18 ppm on Day One, from 0.01 ppm to 0.34 ppm on Day Two, and 0.01 to 0.25 ppm on Day Three. In general, the area concentrations were higher for sterilizers 1–3 and the chemical room, and lower for sterilizers 5, 6. No concentrations are reported for sterilizer 4 due to a failure of the monitor during sampling on Day One. Of note, negative concentrations were observed during the monitoring period even after removing negative readings at initial start-up and allowing the monitor to "warm-up".

Acetic Acid

Average area sampling results for acetic acid can be found in Table C4. The OSHA permissible exposure limit (PEL) and NIOSH recommended exposure limit (REL) for acetic acid are set at 10 ppm. While there are no published OELs for area air samples, they can be used as a reference point to understand potential exposures to employees working in the area. Average concentrations of acetic acid ranged from 0.18 ppm to 1.55 ppm, well below referenced OELs.

Temperature and Humidity

Temperatures ranged from 68.4°F–91.4°F. Relative humidity measurements generally ranged from 49.9%–72.8%, although one measurement reached 86.6%. Temperature and humidity fluctuated based on time of day and location within the facility. During our visit, peak temperatures were recorded between the hours of 9 a.m. and 2 p.m. Peak humidity readings were recorded between the hours of 5 a.m. and 7 a.m. near sterilizer 2 and between 8:30 a.m. and 10 a.m. near sterilizers 3 and 4.

Methods: Document Review

As part of the evaluation, we reviewed the facility specific Respiratory Protection Program, and the results of previous industrial hygiene assessments conducted by a consultant during 2018–2021. The industrial hygiene assessments described the results of air sampling, noise sampling, and temperature and humidity measurements conducted during those years.

Results: Document Review

Respiratory Protection Program Element

This document outlines the administration of the facility respiratory protection program. Respiratory protection is selected based on the nature of tasks or jobs assigned to employees. In the FO department, respiratory protection is required when entering sterilizer cabinets or the chemical room during purges. Voluntary use dust masks are also available to employees for comfort purposes.

2018 Industrial Hygiene Assessment

The 2018 report detailed industrial hygiene sampling results collected for various analytes including PAA and hydrogen peroxide. As a general industrial hygiene practice, if no other action level is specified, measured exposures above an action level of 50% of the OEL can be used to indicate that exposure reduction steps should be taken (NIOSH 1975). Of five personal air samples for PAA, one collected from the FO sterilizer 2 operator measured 0.27 ppm which was greater than 50% of ACGIH TLV-STEL of 0.4 ppm. Of three area samples for PAA, one sample near sterilizer 2 had a concentration of 0.35 ppm. This is also above 50% of the ACGIH TLV-STEL, although the report mentioned that area samples are not directly comparable to the TLV-STEL. All other personal air samples and area samples taken for PAA and hydrogen peroxide were below 50% of any applicable OELs. The report notes that the HVAC system for sterilizer 2 was not operating on the day of sampling.

PAA air concentrations were also measured at sterilizer 2 using a PortaSens PAA direct reading monitor. Measurements were collected at the rear of the machine, near the wall mounted Steri-Trac® PAA wall sensor, at the operator's breathing zone near the sterilizer, and at the machine's front access door. On the back side of the filler, readings greater than 0.4 ppm were noted. The other locations' measurements ranged from 0.19 ppm to 0.28 ppm.

The report detailed an action plan based on the reported findings. Specifically, for sterilizer 2, the consultants recommended that the HVAC system remain in operation when the sterilizer was in use. It was also recommended that the HVAC unit be evaluated, that all potential leaks be identified and repaired as soon as possible, and that the Steri-Trac PAA wall sensors should remain calibrated and in good condition.

2019 Qualitative Health Hazard Assessment Update

The consultant report was a review of 3 years of previous industrial hygiene assessments. It indicated that the most recent PAA and hydrogen peroxide personal air sample results, measured in November of 2018, were all below 50% of the ACGIH limit. The report also indicated the need for baseline sampling at a new production line in the CO department.

2020 Industrial Hygiene Assessment

This report was generated from an industrial hygiene survey conducted in February of 2020. During this survey, which included a baseline survey of the new CO production line, all PAA and hydrogen peroxide air sampling results were below 50% of applicable OELs.

2021 Industrial Hygiene Assessment

This report described the findings of an industrial hygiene survey of FO sterilizers 1, 2 and the CO sterilizer conducted in December of 2021. The surveyors took direct reading PAA measurements at FO sterilizer 2 and the CO sterilizer during this survey. The surveyor noted that a leak was found near FO sterilizer 2 and another noted in the CO sterilizer. Near the leaks, which were not near employee control panels, PAA air concentrations reached 1.1 ppm. Readings taken near employee stations were below 50% of applicable OELs.

Methods: Employee Questionnaires

Informal Employee Interviews

During our initial visit in July 2023, we conducted confidential, structured interviews with a random sample of employees assigned to the FO and CO departments. The goal of these interviews was to gain a better understanding of their work, and any health and safety concerns. We used information from these interviews to develop employee questionnaires.

Questionnaires

During the July 2024 visit, we invited all employees working in the FO and CO departments during the days we were on site, to complete a baseline questionnaire. Each employee scheduled to work during our visit was invited to respond to the baseline questionnaire once. The baseline questionnaire collected information about the employee's work history, typical use of PPE, symptoms experienced during the previous four weeks, underlying medical conditions, demographics, and general health and safety concerns at work.

Based on previous evaluations of PAA exposure and symptoms [Hawley et al. 2018; NIOSH 2018, 2023], the baseline questionnaire asked employees to report if they 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; (10) headache, and (11) any other symptom. When employees reported symptoms that occurred in the previous four weeks, follow-up questions asked employees to report if the symptom was the same, worse, or better, when away from work (either on their days off or when they were on vacation) and if their symptoms were related to a known illness such as a cold, flu, or COVID-19.

After each shift during our visit, employees were invited to complete a brief end-of-shift questionnaire irrespective of whether they had completed the baseline questionnaire. Employees were eligible to complete an end-of-shift questionnaire for any shift worked during the time we were on site. The end of shift questionnaire included questions about job tasks performed during the previous shift, and if employees had experienced any of the symptoms listed above. When employees reported symptoms

during the shift, follow-up questions asked them to report if the symptom was present upon arrival at work and what they were doing when the symptom first began.

Questionnaires were available in English, Spanish, and Haitian Creole.

Outcome Assessment

The main outcomes of interest were self-reported, work-related symptoms occurring during the previous 4 weeks, and during the previous shift. For symptoms during the previous 4 weeks, we defined work-related as a symptom that improved when away from work and was not related to known allergies or an illness. For symptoms during the previous shift, we defined work-related as a symptom that was not present when the employee arrived at work but was experienced during the shift. These definitions are consistent with those used in previous evaluations [Hawley et al. 2018; NIOSH 2018, 2023].

In addition to individual symptoms, we created three composite outcome variables: any symptom, mucous membrane irritation, and lower airway symptoms [Hawley et al. 2018; NIOSH 2018, 2023]. We defined any symptom as report of any one of the symptoms listed above. We defined mucous membrane irritation as report of nasal or eye irritation. We defined lower airway symptoms as cough, wheeze, chest tightness, shortness of breath, or difficulty breathing.

Finally, we estimated the prevalence of underlying medical conditions including asthma, nasal or sinus allergies, eczema or any kind of skin allergy, chronic bronchitis, emphysema, and chronic obstructive pulmonary disease (COPD).

Statistical Analysis

We summarized demographic and work characteristics for all employees completing the baseline questionnaire.

We then estimated the prevalence of acute symptoms and acute, work-related symptoms occurring during the four weeks prior to the visit and during the previous shift.

- We calculated the prevalence of symptoms during the four weeks prior to the visit as the number of employees reporting the symptom on the baseline questionnaire divided by the number of responding employees.
- We calculated the prevalence of symptoms during the previous shift as the number of shifts during which employees reported the symptom divided by the number of completed end of shift questionnaires.

For each prevalence estimate, we calculated 95% confidence intervals (CIs) using the Clopper-Pearson exact method [SAS Institute, no date].

For acute, work-related symptoms during the previous shift, we used log binomial models to estimate associations with work characteristics that may serve as proxies for PAA exposure. Using separate models, we estimated the prevalence of acute, work-related symptoms by department, shift, whether the employee reported working with or around PAA, and sterilizer for those working in the FO department. We estimated prevalence ratios (PR) and 95% CIs to describe associations between these work characteristics and acute symptoms. Because some participants completed more than one end-of-shift questionnaire, we used robust variance estimates to calculate standard errors and 95% CIs. These robust estimates are

equivalent to generalized estimating equation estimates using an independent working covariance matrix. We evaluated age and chronic underlying conditions, and job tenure as possible confounders based on a directed acyclic graph. However, due to small numbers we did not include them in final models.

We also used log binomial models to estimate the association between average area PAA levels by sterilizer and shift and the prevalence of acute work-related symptoms during the previous shift among employees working in the FO department responding to the end-of-shift questionnaires. Each responding employee was assigned the average area PAA level based on their shift and sterilizer worked.

Finally, we summarized free-text responses to a question on the baseline questionnaire about whether the employee had any other workplace safety and health concerns.

We conducted all statistical analyses with SAS statistical software [SAS 9.4, SAS Institute, Cary, North Carolina].

Results: Employee Questionnaires

Demographics, Work Characteristics, and PPE Use of Participating Employees

Fifty-one employees completed a baseline questionnaire (Table C5). The median age of participating employees was 46 years old (range: 23–71 years old). Most participating employees were male (n=45; 88%). Eight participating employees reported currently smoking or vaping, and 14 participating employees reported an allergic condition such as respiratory or skin allergies; no responding employees reported having an asthma diagnosis and fewer than five employees reported other underlying conditions (data not shown).

Most participating employees worked in the FO department (n=43; 84%) where PAA is used in all six sterilizers. The remaining 8 participating employees (16%) worked in the CO department, where PAA was formerly used but was not in use during our visit. Because PAA is used throughout the facility, those working in the CO department may still have the potential for exposure during their shift. Participating employees represented all shifts and job titles present in the facility. Participating employees had worked at the facility for a median 3 years (range: <1 year–45 years) and reported working a median 60 hours per week (range: 40–98 hours). The median hours worked by CO department employees (44 hours; range: 40–60 hours) was lower than the median hours worked by FO employees (60 hours; range: 40–98 hours).

Participating employees reported performing many different tasks as part of their typical work (Table C6). Most (78%) reported working with or around PAA. Job tasks that carried higher potential for PAA exposure included monitoring the sterilizer, responding to jams, cleaning the filler, operating the filler, dealing with a breakdown, helping with problems in the sterilizers or fillers, and transporting and changing PAA totes. Most participating employees (86%) did at least one task with higher potential for PAA exposure.

Participating employees reported variable use of PPE. Approximately 39% of participating employees reported sometimes using a respirator, while 59% reported they never used a respirator. Differences in respirator use are partially related to differences in job tasks, but at least one employee reported that they had not been assigned a respirator and another stated that employees should not have to share respirators indicating that when and how to use respirators may not be clear to all employees. Approximately 31% of participating employees reported always wearing gloves, while 69% reported

sometimes wearing gloves. The largest proportion of participating employees (41%) reported always wearing long pants and long sleeves rolled down. However, some participating employees described hot working conditions that make it difficult to wear long pants and sleeves all the time.

Symptom Prevalence

Symptoms During the Prior Four Weeks

Among all participating employees, 75% (95% CI: 60%, 86%) reported experiencing at least one symptom during the prior four weeks (Table C7). Fifty-one percent (95% CI: 37%, 65%) of participating employees reported a symptom during the prior four weeks that met the work-related definition. The most common work-related symptoms with a prevalence of 20% or more were eye irritation, nasal irritation, sneezing, and throat irritation. Approximately half of participating employees reported experiencing work-related mucous membrane irritation symptoms (eye or nasal irritation) during the prior four weeks (49%; 95% CI: 35%, 63%). The prevalence of work-related lower airway symptoms during the prior four weeks was lower (22%; 95% CI: 11%, 35%).

Symptoms During the Previous Shift

Employees submitted 48 end-of-shift questionnaires; 47 end-of-shift questionnaires included information about symptoms. The prevalence of acute symptoms during the previous shift was 49% (95% CI: 34%, 64%), with a prevalence of 40% (95% CI: 26%, 86%) for work-related symptoms (Table C7). The most common work-related symptoms with a prevalence of 20% or more were eye irritation and nasal irritation. Approximately a third of participating employees reported experiencing work-related mucous membrane irritation symptoms (eye or nasal irritation) during the previous shift (32%; 95% CI: 20%, 47%). The prevalence of work-related lower airway symptoms during the previous shift was lower (11%; 95% CI: 4%, 23%).

Employees experiencing work-related symptoms during the previous shift reported that they began while doing various activities. Some reported that symptoms began upon entering the building, after entering specific areas including the chemical room, areas where the oldest sterilizers were located, and the systems area. Other employees reported symptoms began after running the packer, running the production line for many hours, or completing their normal job tasks assisting on the production line. Employees also reported symptoms beginning after operating the molder or addressing a jam.

Associations Between Work Characteristics, PAA Exposure, and Symptoms

Among all participating employees, prevalence of acute symptoms was elevated for employees reporting work with or around PAA compared with those who did not, although differences were not statistically significant (Table C8).

Among employees working in the FO department where PAA was actively being used, the prevalence of all types of acute, work-related symptoms was highest during third shift (Table C9); the prevalence of acute, work-related mucous membrane symptoms was 2.86 times the prevalence among first shift, and this difference was statistically significant (95%: 1.03, 7.92).

Consistent with the measured levels of PAA, the prevalence of work-related symptoms was also highest among those working on sterilizers 2, 3, and 4 compared with those working on sterilizer 1 or sterilizers 5

and 6, although these differences were not statistically significant (Table C10). We found no statistically significant associations between average area PAA concentrations and symptom types (Table C11).

Health and Safety Concerns

Fifteen of the 51 employees completing a baseline questionnaire (29%) shared at least one health and safety-related concern. The most common concern, reported by multiple employees, was about working in the heat. Employees described high temperatures (>90°F), little air circulation, and experiencing symptoms such as excessive sweating and leg cramps. Employees cited the heat in the FO department on sterilizers 3 and 4 as concerning, especially in the presence of PAA. For example, an employee reported that on sterilizers 3 and 4 when cleaning and sterilization procedures are being conducted "the air is unbearable."

PAA exposure was also noted as a common concern. Specifically, employees were concerned about leaks that allow PAA to be released on the production line and having little information about the potential long-term health effects of chronic exposure to PAA. Employees noted concerns about acute symptoms such as eye, nose, and throat irritation and skin rashes. Employees described concerns that the sensors used to alarm them about levels of PAA do not always work. Finally, employees noted a difference in potential PAA exposure concerns by sterilizer. One employee noted that when they work on FO sterilizer 6, PAA exposure is not as bad, but when they work on FO sterilizers 3 and 4 the effects of PAA are especially bad, particularly when they need to open the sterilizer doors.

Employees also reported concerns about PPE including that eye protection fogs when driving a forklift in and out of cold storage rooms, not being assigned a respirator, sharing respirators, and that bump caps are too hot.

Methods: Observations of Work Processes and Work Practices

We conducted observations of workplace processes and practices within the FO and CO departments.

Results: Observations of Work Processes and Work Practices

During our visits, we identified several factors that could contribute to elevated PAA concentrations in the workplace. We noted PAA leaking from sterilizer entry points and PAA piping systems throughout the facility. We inquired about scheduled preventative maintenance including replacing gaskets and plastic components of these systems and were informed there was no known schedule in place. We also asked about scheduled ventilation maintenance such as airflow measurements and filter change out; however, employees and management could not provide information on this topic. We observed areas on the older sterilizers where, presumably, the disinfectant had worn away plastic locks and rubber gaskets. Because of this, PAA had seeped through the joints and entry points of the sterilizer, causing discoloration on the outside metal work. We noted the scent of PAA was heightened in these areas compared to the sterilizers without seepage or discoloration.

Employees exhibited a range of knowledge about PAA control measures to reduce exposures including facility policy, procedures, and PPE use. Of note, employees described no standard response to PAA sensor readings above the TLV-STEL. Some sensors had even been unplugged due to continuous alarms. While respirators were not required for most tasks, some employees who worked on sterilizers

were assigned respirators for voluntary use and provided with appropriate training, others reported they were not provided with either. In addition, some employees reported that they open sterilizers without donning respirators, although respirators are required when working in sterilizer cabinets.

Discussion

PAA is now a commonly used product for sterilization in a range of industries [Yuan et al. 2025]. Although PAA is known to irritate the eyes and mucous membranes of the upper respiratory tract, little information is available in the scientific literature about levels of PAA in air observed in various workplaces or symptoms experienced by exposed employees. This evaluation demonstrated that although employees at this beverage manufacturing facility were exposed to PAA levels typically below the only available OEL, symptoms such as chronic and acute nasal and eye irritation were common.

Because of the difficulty of measuring PAA in air, limited data on PAA exposure levels 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 hydrogen peroxide 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. method and ChemDAQ direct-reading instruments, to measure exposures to PAA during hospital endoscope disinfection processes. The different sampling methods showed good agreement. Based on this previous research showing the feasibility of using the Hecht et al. method for measuring PAA, we used this method for our PAA measurement during this health hazard evaluation (HHE). NIOSH scientists have used this method in previous HHEs and other evaluations among federal poultry inspectors in poultry processing facilities [NIOSH 2016, 2017], among hospital workers [NIOSH 2015, 2016, 2017, 2025b,c] and at pork processing facilities [NIOSH 2024, 2025a].

The OSHA PEL and NIOSH REL for hydrogen peroxide is 1 ppm for an 8-hour exposure, with a 15-minute TLV-STEL of 1 ppm set by ACGIH. The PEL and REL for acetic acid is 10 ppm, though we did not conduct personal sampling for acetic acid during this evaluation. OSHA, NIOSH, and ACGIH do not have OELs for area air samples; this means area measurements cannot be directly compared to existing OELs, which are established for personal exposures. However, area sample results may represent a reasonable approximation of potential exposures for employees because employees were stationed at work locations near where the measurements were taken.

Average measured PAA, hydrogen peroxide and acetic acid concentrations for all areas sampled were below their respective OELs. However, we observed some individual area measurement concentrations of PAA exceeding the ACGIH TLV-STEL, specifically around sterilizers 2 and 3 and during first and second shifts. The age of the sterilizers, and inadequate maintenance, likely contributed to PAA levels in the work area with older lines (2, 3, and 4) having higher levels and more variability compared with newer lines (5 and 6). Several factors could contribute to PAA concentrations exceeding the ACGIH TLV-STEL during the first two shifts. These factors include staffing, production rates, and equipment maintenance activities. Heat and humidity are additional factors that may influence levels of PAA, as research has shown that PAA's disinfection activity increases with higher temperatures and humidity

[Yuan et al. 2025]. During times of day where there are higher temperatures and humidity levels, PAA vapors may behave differently, potentially causing slightly increased measurable concentrations.

Although most area and personal PAA sample measurements were below the only available OEL, employees reported experiencing a range of work-related symptoms. Acute exposure to PAA has been shown to cause irritation of the eyes, skin, and upper respiratory tract [Pechacek et al. 2015]. In addition, asthma associated with PAA exposure in healthcare workers has been reported [Cristofari-Marquand et al. 2007]. Similar to previous evaluations of hospital employees working with or around cleaning agents containing PAA, chronic and acute work-related mucous membrane irritation symptoms, including eye and nasal irritation, were the most commonly reported symptoms [Hawley et al. 2016; Hawley et al. 2018; NIOSH 2018, 2023]. In previous evaluations of federal poultry inspectors, irritation of the eyes, nose, and throat were the most common symptoms reported [NIOSH 2016, 2017].

We did not find a statistically significant association between measured area air concentrations of PAA and the occurrence of work-related symptoms during the previous shift. Previous evaluations have observed statistically significant positive associations between exposure to PAA and work-related acute, cross-shift symptoms and symptoms during the previous four weeks [NIOSH 2018, 2023]. It is possible that we did not find significant associations because of limitations including small sample size and an inability to control for potential confounding factors. It is also possible that since we were only able to measure PAA concentrations in air for limited periods of time, we may have missed periods of time when higher or lower PAA exposures may have occurred. Despite this, symptoms were consistently more prevalent among employees working around sterilizers where higher concentrations of PAA were found in air compared with employees working around the newer sterilizers, which had lower air concentrations of PAA.

Work-related mucous membrane symptoms, defined as nasal or eye irritation, were more commonly reported by third shift employees compared with first and second shift employees. This finding was surprising in that the distribution of PAA levels appeared relatively similar across the three shifts, and peak levels of PAA exceeding the ACGIH TLV were observed during first and second shift but not during third shift. Previous work suggested that symptoms of discomfort or irritation can occur at PAA levels in air less than 0.4 ppm depending on duration of exposure, but no specific threshold of PAA exposure above which irritation symptoms would be expected has been established [Hawley et al. 2018; NAS 2010; Pechacek et al. 2015]. This may be because many other factors in addition to intensity and duration of a specific exposure may influence whether a person experiences symptoms. Those factors include but are not limited to occupational or environmental factors (e.g., lifetime duration or frequency of exposure to PAA, temperature and humidity) and personal factors (e.g., age, gender, underlying conditions). Therefore, in this evaluation we cannot determine why third shift employees reported a higher prevalence of symptoms, but this information indicates that understanding the occurrence of symptoms may be useful in identifying locations and times to evaluate for improvements.

When used correctly, direct reading PAA monitors can be a valuable tool in the workplace. They provide a quick snapshot of approximate PAA concentrations in air, which can provide additional time to act if unexpected changes in concentration occur. While they are useful tools, there are also some limitations to consider. PAA sensors can be sensitive to temperature and humidity and can be cross-reactive to certain

chemicals such as chlorine, ozone, and hydrogen peroxide [USDA 2020]. This means that readings at times may reflect concentrations that are higher or lower than actual employee exposures.

We inquired about the placement of direct reading PAA monitors during our visit. Sensors were placed several feet above employee breathing zones. Sensors were occasionally placed above fans or had nearby fans blowing air directly across the sensors. Placement of sensors above employee breathing zones may reduce the value of the sensor measurement results with regards to employee exposures and control measure efficacy. Blowing air near or on sensors can dilute measured PAA values and underestimate employee exposures. To get the most accurate measures of employee PAA exposures, monitors should be placed in areas where air movement will not interfere with measured results and at a height between five and six feet above the ground to be representative of employee breathing zones.

One notable phenomenon observed within the data from the direct reading instruments for PAA was the presence of negative values recorded at the beginning of each shift. Similar readings were also seen on the facility monitors. Negative values have been observed in other NIOSH sampling efforts and noted when communicating with external companies with their own PAA direct reading monitors. We are not aware of documentation of this phenomenon in any published literature. Between 15–75 minutes after the instruments were deployed, the instruments began reading non-negative values. One possibility is that both the instrument sensors and data logger should be turned on for a period of time prior to sampling to "warm-up." During the evaluation we tried zeroing the instruments prior to sampling in the plants, but software errors prevented this procedure which led to the decision to remove negative concentration readings at the beginning of the instrument's data logging until zero and positive concentrations were consistently logged. Despite these challenges, the PAA concentration levels as a whole were relatively consistent with the area Hecht et al. [2004] method concentrations.

The temperature and humidity fluctuated based on time of day and location within the facility. Peak temperatures were recorded near sterilizers 2, 3, and 4. These findings reinforce employee concerns conveyed during interviews about hot working conditions and that the heat may potentially affect the occurrence of symptoms related to PAA exposure, especially when working near the older sterilizers. Improving the ventilation system temperature and humidity control can help address employee heat stress concerns. In addition, improving the ventilation system can increase the capture of PAA vapors and reduce employee exposures to PAA.

Conclusion

Levels of PAA in air were mostly below the ACGIH TLV-STEL of 0.4 ppm, the only available OEL. Despite this, chronic and acute work-related symptoms, specifically mucous membrane irritation symptoms, were common among employees. Work-related lower respiratory symptoms were also reported by employees but were less common. Although we did not consistently observe statistically significant associations between work characteristics or measured PAA exposure and the prevalence of symptoms, previous literature supports associations between these factors and symptoms. Taken together with existing information, our results indicate a need to (1) use a combination of preventative maintenance, and engineering and administrative controls to reduce employee exposures, and (2) monitor respiratory and eye symptoms among employees working with or around PAA.

Limitations

This evaluation had a cross-sectional design, which means that information on exposures and health outcomes was collected at one point in time. Cross-sectional evaluations provide useful information that can inform recommendations for improving workplace safety and health. However, industrial hygiene sampling and an engineering control evaluation can only document exposures and conditions on the days and in the locations evaluated. These results may not be representative of conditions during other days or on other work sites.

In addition, the healthy worker survivor effect is an inherent bias of the cross-sectional design. Employees that remain on the job (sometimes referred to as survivors) are usually healthier or more able to deal with the environment than those who leave employment. Because cross-sectional studies do not include former employees, such as those who leave their job because they experience symptoms, the healthy worker survivor effect can lead to an underestimate of the burden of symptoms.

Using questionnaires, we focused on symptoms that employees experienced during the previous four weeks and during the most recent shift. This information is limited to symptoms occurring during those relatively short periods of time. Focusing on recent periods is helpful in reducing bias from employees needing to remember and accurately report symptoms, events, or knowledge. However, if conditions have changed over time, our results will not be representative of employees' experiences at other times.

In this evaluation, we invited employees to complete questionnaires independently in writing before and after their shift. Although NIOSH staff were available for questions or assistance, it is possible that this method of data collection could have affected participation or resulted in larger amounts of missing data than if NIOSH staff interviewed employees. This method also can result in an inability to correct any misunderstanding of questions, possibly resulting in incorrect or missing information.

The Hecht et al. [2004] method may underestimate exposures when PAA is applied as a spray.

Although not a limitation of this HHE, it is important to note that the findings reported here are specific to this plant and may not be generalizable to other beverage processing plants.

Section C: Tables

Table C1. Short term personal breathing zone air sampling results for peracetic acid (PAA), July 2024

Sterilizer #	Shift 1 measured concentrations (ppm)	Shift 2 measured concentrations (ppm)	Shift 3 measured concentrations (ppm)
1	0.03	0.08	0.09
	0.22	0.09	0.11
	0.01	0.07	ND
2	0.34	0.15	0.26
	0.23	0.16	0.28
	0.30	0.14	0.28
	0.34		
	0.38		
	0.41		
3	0.13	*	*
	0.21		
	0.14		
4	0.35	0.19	*
	0.26	0.17	
	0.26	0.18	
	0.11		
	0.16		
	0.21		
5	0.03	*	0.02
			0.02
			0.01
6	0.024	0.015	0.01
	0.016	0.012	ND
	0.015	0.013	0.01

ppm = parts per million

ND= non detect

* Indicates that there is no data available for specified shift/sterilizer

Table C2. Average short term area sampling results for peracetic acid (PAA), July 2024

Shift	Sterilizer number	Number of samples	Average PAA concentration (ppm)
1	1	9	0.11
	2	8	0.33
	3	3	0.20
	4	11	0.12
	5	5	0.03
	6	9	0.02
2	1	7	0.12
	2	8	0.18
	3	12	0.25
	4	4	0.27
	5	10	0.03
	6	3	0.01
3	1	4	0.06
	2	3	0.31
	3	6	0.27
	4	3	0.25
	5	2	0.03
	6	3	0.01

ppm = parts per million

Table C3. Direct reading instrument peracetic acid (PAA) measurements, July 2024

Location		Day 1 concentrations (ppm)	Day 2 concentrations (ppm)	Day 3 concentrations (ppm)
Sterilizer 1	Minimum	0.04	†	†
	Maximum	0.42	†	†
	Average	0.14	†	†
Sterilizer 2	Minimum	0.00	0.00	0.00
	Maximum	0.35	0.47	0.40
	Average	0.12	0.34	0.25
Sterilizer 3	Minimum	-0.07	0.00	†
	Maximum	1.56	0.63	†
	Average	0.18*	0.27	†
Sterilizer 5	Minimum	-0.01	-0.04	-0.02
	Maximum	0.03	0.09	0.09
	Average	0.01*	0.01*	0.01*
Sterilizer 6	Minimum	-0.04	†	†
	Maximum	0.04	†	†
	Average	0.03*	†	†
Chemical Room	Minimum	-0.01	†	0.00
	Maximum	0.28	†	0.22
	Average	0.02*	†	0.03*

ppm = parts per million

* Negative values were removed from calculated averages.

† Indicates there is no data available for specified sterilizer/area.

Note: Due to monitor failure, there is no data available for sterilizer 4.

Table C4. Average partial shift area sampling results for acetic acid, July 2024

Sterilizer Number	Average concentration (ppm)
1	0.77
2	1.55
3	1.32
4	1.14
5	0.18
6	*

ppm = parts per million

* Indicates that no data is available for that sterilizer

Table C5. Distribution of demographics and work-related information of employees responding to the baseline questionnaire (n = 51), July 2024

	N = 51	%
Demographics		
Age (median; range)	46 (23–71)	
Age categories		
<40 years old	18	35
40–59 years old	25	49
≥60 years old	8	16
Sex		
Male	45	88
Female	6	12
Current smoking or vaping		
Yes	8	17
No	40	83
Missing	3	
Allergic condition		
Yes	14	29
No	35	71
Missing	2	
Work characteristics		
Department		
Filling operations	43*	84
Carton operations	8	16
Typical shift		
First	12	24
Second	16	32
Third	19	38
Multiple	3	6
Missing	1	
Current job title		
Operator	19	37
Operator mechanic	18	35
Specialist	7	14
Supervisors/leaders	7	14
Years worked (median, range)	3 (<1–45)	
Years worked (categories)		
<2 years	8	16
2–4 years	19	39
5–9 years	4	8
≥10 years	18	37
Missing	2	
Hours worked per week (median; range)	60 (40–98)	

* Includes one person who reported working in all departments.

Table C6. Job tasks performed by employees responding to the baseline questionnaire (n = 51), July 2024

	N = 51	%
Worked with or around PAA		
Yes	40	78
No	9	18
Missing	2	
Job task		
Monitor the production line	37	73
Responded to jam	32	63
Clean filler	30	59
Operate filler	30	59
Deal with breakdown	25	49
Help with problems in the sterilizers or fillers	25	49
Check oils and fluids	23	45
Check cartons	6	12
Operate forklift	31	61
Operate SSL9	4	8
Check product	23	45
Analyze samples	11	22
Perform equipment maintenance	21	41
Change pumps	16	31
Run Labeler	25	49
Other*	8	16
Job tasks categories†		
Higher potential for PAA exposure	44	86
Lower potential for PAA exposure	7	14

* Other job tasks reported include transporting and changing PAA totes, run blow molder, run case packer, and system operator.

† Higher potential for PAA exposure job tasks included: monitor the production line, respond to jam, clean filler, operate filler, deal with breakdown, help with problems in the sterilizers or fillers, and some tasks specified in other including transporting and changing PAA totes. Lower potential for PAA exposure job tasks included all other tasks.

Table C7. Prevalence of symptoms experienced during the prior 4 weeks and during the previous shift as reported by employees responding to the baseline or post-shift questionnaire

	Last 4 weeks					Previous shift				
		Overall		Work-related			Overall		Work-related	
	Number of responding employees	N	Prevalence (95% CI)	N	Prevalence (95% CI)	Total number of shifts	N	Prevalence (95% CI)	N	Prevalence (95% CI)
Any symptom	51	38	75% (60%, 86%)	26	51% (37%, 65%)	47	23	49% (34%, 64%)	20	40% (26%, 54%)
Eye irritation	50	29	58% (43%, 72%)	21	42% (28%, 56%)	47	14	30% (17%, 45%)	11	23% (12%, 38%)
Nasal irritation	50	28	56% (41%, 70%)	18	36% (23%, 51%)	47	15	32% (19%, 47%)	11	22% (12%, 36%)
Sneeze	49	25	51% (36%, 66%)	13	27% (15%, 41%)	45	11	24% (13%, 40%)	6	13% (5%, 27%)
Throat irritation	50	14	28% (16%, 42%)	10	20% (10%, 34%)	47	10	21% (11%, 36%)	7	15% (6%, 28%)
Cough	49	15	31% (18%, 45%)	9	18% (9%, 32%)	47	4	9% (2%, 20%)	2	4% (1%, 15%)
Headache	49	15	31% (18%, 45%)	7	14% (6%, 27%)	47	2	4% (1%, 15%)	1	2% (0%, 11%)
Wheeze or whistling in chest	49	7	14% (6%, 27%)	3	6% (1%, 17%)	46	3	7% (1%, 18%)	2	4% (1%, 15%)
Shortness of breath	48	6	13% (5%, 25%)	4	8% (2%, 20%)	46	2	4% (1%, 15%)	1	2% (0%, 12%)
Difficulty breathing	46	5	11% (2%, 20%)	2	4% (1%, 15%)	46	1	2% (0%, 12%)	1	2% (0%, 12%)
Chest tightness	48	4	8% (2%, 20%)	2	4% (1%, 14%)	46	2	4% (1%, 15%)	2	4% (1%, 15%)
Symptom type										
Acute mucous-membrane irritation*	51	36	71% (56%, 83%)	25	49% (35%, 63%)	47	18	38% (25%, 54%)	16	32% (20%, 47%)
Lower airway symptoms†	49	18	35% (22%, 50%)	11	22% (11%, 35%)	47	7	15% (6%, 28%)	5	11% (4%, 23%)

* Acute mucous membrane is defined as nasal or eye irritation.

† Lower airway symptoms include cough, wheeze, chest tightness, shortness of breath, or difficulty breathing.

Table C8. Prevalence of symptoms during the previous shift reported on end of shift questionnaires by employees who reported working with peracetic acid (PAA) compared with employees who did not report working with PAA

	Total	N	Prevalence	PR (95% CI)
Any symptom				
Did not work with PAA	14	2	14%	Ref
Worked with PAA	33	18	53%	3.71 (0.98, 14.03)
Acute mucous membrane irritation				
Did not work with PAA	14	2	14%	Ref
Worked with PAA	33	14	41%	2.88 (0.75, 11.14)
Lower airway symptoms				
Did not work with PAA	14	0	0%	Ref
Worked with PAA	33	5	15%	NC

PR = prevalence ratio

CI = confidence interval

Ref = reference group

NC = not calculated

Table C9. Prevalence of symptoms during the previous shift reported on end of shift questionnaires by employees working in the FO department by shift

	Total*	N	Prevalence	PR (95% CI)
Any symptom				
Shift 1	12	5	42%	Ref
Shift 2	16	4	25%	0.60 (0.20,1.79)
Shift 3	14	11	79%	1.89 (0.92, 3.87)
Mucous membrane irritation				
Shift 1	12	3	25%	Ref
Shift 2	16	3	19%	0.75 (0.18, 3.12)
Shift 3	14	10	71%	2.86 (1.03, 7.92)
Lower airway symptoms				
Shift 1	12	1	8%	Ref
Shift 2	16	0	0%	NC
Shift 3	14	4	25%	NC

PR = prevalence ratio

CI = confidence interval

Ref = reference group

NC = not calculated

* A total of 42 end-of-shift questionnaires were submitted by FO department employees with information on shift worked.

Table C10. Prevalence of symptoms during the previous shift reported on end of shift questionnaires by employees working in the FO department by sterilizer worked

	Total*	N	Prevalence	PR (95% CI)
Any symptom				
Sterilizer 1	4	1	25%	0.58 (0.09, 3.90)
Sterilizers 2, 3, 4	22	13	59%	1.38 (0.55, 3.47)
Sterilizers 5, 6	7	3	43%	Ref
Acute mucous membrane irritation				
Sterilizer 1	4	1	25%	0.88 (0.11, 6.88)
Sterilizers 2, 3, 4	22	10	45%	1.59 (0.45, 5.60)
Sterilizers 5, 6	7	2	29%	Ref
Lower airway symptoms				
Sterilizer 1	4	0	0%	NC
Sterilizers 2, 3, 4	22	4	18%	NC
Sterilizers 5, 6	7	0	0%	Ref

PR = prevalence ratio

CI = confidence interval

Ref = reference group

NC = not calculated

* A total of 33 end-of-shift questionnaires were submitted by FO department employees with information on sterilizer worked during the previous shift.

Table C11. Prevalence ratios (95% confidence intervals) describing the association between a 0.05-unit increase in PAA levels and prevalence of symptoms during the previous shift among employees working in the FO department

	Total*	N	PR (95% CI)
Any symptom	30	15	1.13 (0.94, 1.37)
Acute mucous membrane irritation	30	11	1.18 (0.93, 1.50)
Lower airway symptoms	30	4	NC

PR = prevalence ratio

CI = confidence interval

NC = not calculated

* Total number of end-of-shift questionnaires from FO department employees with information on sterilizer and shift worked.

Section D: Occupational Exposure Limits

NIOSH investigators refer to mandatory (legally enforceable) and recommended occupational exposure limits (OELs) for chemical, physical, and biological agents when evaluating workplace hazards. OELs have been developed by federal agencies and safety and health organizations to decrease the risk of adverse health effects from workplace exposures. Generally, OELs suggest levels of exposure that most employees may be exposed to for up to 10 hours per day, 40 hours per week, for a working lifetime, without experiencing adverse health effects.

However, not all employees will be protected if their exposures are maintained below these levels. Some may have adverse health effects because of individual susceptibility, a preexisting medical condition, or a hypersensitivity (allergy). In addition, some hazardous substances act in combination with other exposures, with the general environment, or with medications or personal habits of the employee to produce adverse health effects. Most OELs address airborne exposures, but some substances can be absorbed directly through the skin and mucous membranes.

Most OELs are expressed as a time-weighted average (TWA) exposure. A TWA refers to the average exposure during a normal 8- to 10-hour workday. Some chemical substances and physical agents have recommended short-term exposure limits (STEL) or ceiling values. Unless otherwise noted, the STEL is a 15-minute TWA exposure. It should not be exceeded at any time during a workday. The ceiling limit should not be exceeded at any time.

In the United States, OELs have been established by federal agencies, professional organizations, state and local governments, and other entities. Some OELs are legally enforceable limits; others are recommendations.

- OSHA, an agency of the U.S. Department of Labor, publishes permissible exposure limits [29 CFR 1910 for general industry; 29 CFR 1926 for construction industry; and 29 CFR 1917 for maritime industry] called PELs. These legal limits are enforceable in workplaces covered under the Occupational Safety and Health Act of 1970. The Occupational Safety and Health Act requires employers to provide a safe workplace.
- NIOSH recommended exposure limits (RELs) are recommendations based on a critical review of the scientific and technical information and the adequacy of methods to identify and control the hazard. NIOSH RELs are published in the NIOSH Pocket Guide to Chemical Hazards [NIOSH 2007]. NIOSH also recommends risk management practices (e.g., engineering controls, safe work practices, employee education/training, personal protective equipment, and exposure and medical monitoring) to minimize the risk of exposure and adverse health effects.
- Another set of OELs commonly used and cited in the United States includes the threshold limit values or TLVs, which are recommended by the American Conference of Governmental Industrial Hygienists (ACGIH). The ACGIH TLVs are developed by committee members of this professional organization from a review of the published, peer-reviewed literature. TLVs are not consensus standards. They are considered voluntary exposure guidelines for use by industrial

hygienists and others trained in this discipline "to assist in the control of health hazards" [ACGIH 2025].

Outside the United States, OELs have been established by various agencies and organizations and include legal and recommended limits. The Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung (Institute for Occupational Safety and Health of the German Social Accident Insurance) maintains a database of international OELs from European Union member states, Canada (Québec), Japan, Switzerland, and the United States. The database contains international limits for more than 2,000 hazardous substances and is updated periodically.

OSHA (Public Law 91-596) requires an employer to furnish employees a place of employment free from recognized hazards that cause or are likely to cause death or serious physical harm. This is true in the absence of a specific OEL. It also is important to keep in mind that OELs may not reflect current health-based information.

When multiple OELs exist for a substance or agent, NIOSH investigators generally encourage employers to use the lowest OEL when making risk assessment and risk management decisions.

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