Evaluation of Peracetic Acid Exposure Among Federal Poultry Inspectors

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Contents

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

Highlights of this Evaluation

The Health Hazard Evaluation Program received a request from federal employee managers at a United States Department of Agriculture Food Safety and Inspection Service inspected poultry processing plant. The managers were concerned about federal inspectors' potential health effects from exposure to disinfectants used on the plant's processing line.

What We Did

- We visited the poultry processing plant in July 2016.
- We observed work practices.
- We interviewed federal inspectors about their work, their health, and their concerns.
- We reviewed a summary of federal inspector's notices of traumatic injury.
- We evaluated the ventilation in the evisceration area.
- We took personal air samples for peracetic acid, hydrogen peroxide, and acetic acid.

We evaluated federal inspectors' exposures to peracetic acid, hydrogen peroxide, and acetic acid. We found low airborne concentrations of the three chemicals in the evisceration department. Some employees reported occasional eye and nasal irritation. The addition of single-pass mechanical ventilation for the entire plant improved workplace conditions.

What We Found

- We found low levels of peracetic acid, hydrogen peroxide, and acetic acid on inspectors working in the evisceration area. None of the samples exceeded occupational exposure limits.
- Some employees reported occasional eye and nasal irritation. These symptoms can be caused by exposure to chemicals used in the plant, including peracetic acid, hydrogen peroxide, and acetic acid.
- We found that employees were using latex gloves, which have been associated with allergic reactions.

What the Employer Can Do

- Encourage employees to report workplace health concerns to supervisors.
- Periodically and after incidents and near-misses, provide refresher training on the prevention of slips, trips, and falls for inspectors.
- Ensure that employees have the required personal protective equipment including eye and skin protection. Train employees on its use.
- Provide nitrile gloves instead of natural rubber latex gloves to protect employees' skin from dermal exposures.

What Employees Can Do

- Wear required personal protective equipment.
- Use nitrile, rather than latex gloves, because of the potential for allergic reactions to latex.
- Report workplace health concerns to your employer.

Abbreviations

ACGIH®	American Conference of Governmental Industrial Hygienists
CFR	Code of Federal Regulations
FSIS	Food Safety and Inspection Service
MDC	Minimum detectable concentration
MQC	Minimum quantifiable concentration
NA	Not applicable
ND	Not detected
NIOSH	National Institute for Occupational Safety and Health
OEL	Occupational exposure limit
OSHA	Occupational Safety and Health Administration
PEL	Permissible exposure limit
ppm	Parts per million
REL	Recommended exposure limit
STEL	Short-term exposure limit
TLV®	Threshold limit value
TWA	Time-weighted average
USDA	United States Department of Agriculture

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Introduction

The Health Hazard Evaluation Program received a request from a management representative of the United States Department of Agriculture Food Safety and Inspection Service (USDA/FSIS). The request concerned potential exposures of USDA/FSIS employees at a poultry processing plant to peracetic acid and other chemical disinfectants. In July 2016, we evaluated the evisceration area of the poultry plant. We prepared a letter detailing our evaluation and preliminary recommendations in July 2016 and a summary of air monitoring results in November 2016. We sent these letters to the poultry company, USDA/FSIS managers, and USDA/FSIS employee union representatives. We also provided individual air monitoring results to participants in November 2016.

During our evaluation, the poultry plant processed 210,000–230,000 birds per day with an average of 1 million birds per week. The birds averaged 4–6 pounds. The plant had two slaughter shifts and one sanitation shift. The plant had three evisceration lines; two lines operated at 70 birds per minute and had two federal inspectors each, and one line operated at 91 birds per minute and had three federal inspectors. Inspectors visually checked carcasses for signs of infection or other defects. Ten USDA/FSIS employees typically worked on each slaughter shift. Seven were on-line inspectors in the evisceration area, two were consumer safety inspectors, and one was a public health veterinarian. Poultry slaughter and cut-up occurred at this location; no breading, marinating, or other further processing took place. Required personal protective equipment for USDA/FSIS employees on the evisceration line included a laboratory coat, hard hat, hair net, beard net (if needed), latex gloves, hearing protection (insert-type plugs), fluid-resistant apron, and nonslip rubber boots. Rubber gloves were also available for employees to use.

Peracetic acid solution and chlorine were the only antimicrobial products used in the vicinity of the evisceration department at the time of our evaluation. In the evisceration department after inspection, the chicken pieces were sprayed with the peracetic acid solution in three separate enclosed cabinets, one for each line. Peracetic acid disinfection had been introduced into the plant about 3 years before this site visit. Chlorine was used in the three main chiller tanks and the rework area. Perasafe™ Direct Meat (manufactured by AFCO) was used in the rocker chiller and the chill tank for chicken wings. The formulation of Perasafe, according to the AFCO safety data sheet, was about 15% peracetic acid, 10% hydrogen peroxide, and 35% acetic acid. Chlorine and the peracetic acid solution were stored in separate chemical rooms outside the main building. The chemicals were added automatically to the appropriate chiller to maintain the effective concentration. Chlorine and peracetic acid solution were piped into the tanks using an automated system when needed to maintain effective concentrations (about 55 parts per million [ppm] peracetic acid and 30 ppm for chlorine). FSIS allows up to 2,000 ppm peracetic acid for use on food products [USDA 2017]. Plant employees used direct reading titration kits to test the concentration of peracetic acid and chlorine hourly. In the cut-up department which we did not evaluate, Cecure®, a USDA-approved cetylpyridinium chloride disinfectant manufactured by Safe Foods Corporation, was used in an enclosed system.

Used peracetic acid solution was not recirculated. About a year before the site visit, the plant had installed a separate drainage system for the peracetic acid solution waste stream that led directly to the wastewater treatment plant. Used chlorine solution from the plant processes including evisceration that occurred before bird washing was recirculated. The chlorine solution passed through a large metal screen filter followed by a fine metal screen filter with a 200-micrometer pore size to remove particulates. The resulting solution was tested for chlorine concentration; additional chlorine was added to obtain the effective chlorine concentration, and then reused. The chlorine solution from the other processes had a separate drainage system to the wastewater treatment plant.

Background

Peracetic acid solutions typically consist of a mixture of peracetic acid, acetic acid, and hydrogen peroxide in various concentrations. Acute exposure to peracetic acid has been shown to cause irritation of the eyes, skin, and upper respiratory tract [New Jersey Department of Health and Senior Services 2004; Pechacek et al. 2015]. Previous National Institute for Occupational Safety and Health (NIOSH) health hazard evaluations of chlorine disinfection processes at other poultry plants found that employees reported respiratory and eye irritation in evisceration departments that used chlorine [NIOSH 2003, 2006, 2007, 2012]. Additional information and occupational exposure limits (OELs) for these disinfectants can be found in Appendix B.

Methods

The objectives of this evaluation were to determine the extent of USDA/FSIS inspectors' exposures to peracetic acid and whether employees had work-related symptoms. We observed workplace conditions and work processes and practices. We reviewed a summary of injury reports and held confidential medical interviews with USDA/FSIS employees. We also asked questions about whether the following were problems at work: workload or production speed, effectiveness of safety policies and procedures, scheduling and overtime, job stress, and job security. Because this was a USDA/FSIS request, we did not interview the poultry plant employees. We offered to include plant employees in our evaluation, but plant managers declined. We looked at the ventilation system that served the plant including the evisceration department. We reviewed how peracetic acid was added to the dip and chill tanks and the titration method used to verify its concentration.

We collected four personal air samples on second slaughter shift employees for acetic acid using Occupational Safety and Health Administration (OSHA) Method PV2119 [OSHA 2017]. We collected three short-term personal air samples for hydrogen peroxide and peracetic acid on three inspectors on the first slaughter shift. We also collected sequential, short duration personal air samples for hydrogen peroxide and peracetic acid on two inspectors throughout the second slaughter shift for a total of 24 samples on one inspector and 25 samples on a second inspector. For analysis of peracetic acid and hydrogen peroxide exposures, we combined these short-term sample results to calculate full-shift time-weighted average (TWA) exposures. Values for the exposure measurements that were below the minimum detectable concentration (MDC) were estimated by dividing the MDC by the square root of 2 [Hornung and Reed 1990]. Hydrogen peroxide and peracetic acid samples were taken at a flowrate of 1 liter per minute. The hydrogen peroxide samples were collected on treated filters (SKC #225-9030) and digested with sulfuric acid. The samples were centrifuged, and the extract was read using ultraviolet-visible spectrophotometry following an analytical method described by Hecht et al. [2004]. The peracetic acid samples were collected on silica gel tubes (SKC #226-193) and desorbed with acetonitrile. The samples were then diluted with deionized water. The solutions were analyzed using high-performance liquid chromatography according to an in-house method from the NIOSH contract laboratory based on the Hecht et al. method [2004]. The Hecht et al. method may underestimate exposures when peracetic acid is applied as a spray [2004].

Results and Discussion

Employee Interviews and Record Reviews

We held confidential, voluntary medical interviews with all 13 USDA/FSIS employees who either worked at the plant full-time on the second slaughter shift or who rotated shifts between this plant and other local slaughter establishments (relief inspectors). We focused on the second (overnight) slaughter shift because in the past most health concerns were expressed by employees on this shift. Job titles included supervisory public health veterinarian, line inspector, and consumer safety inspector. We discussed previous injuries or illnesses related to work; current health status and symptoms; health history; and employee perceptions of communication, work organization, job stress, and other safety or health concerns. We reviewed summary information collected from Federal Employee's Notice of Traumatic Injury and Claim for Continuation of Pay/Compensation (Form CA-1). This information was provided by staff from USDA/FSIS Office of Employee Safety, Health, and Wellness.

Employee Interviews

Participants reported working at this processing plant an average of 44 months (median: 14 months) with a range from 1 day to 20 years. Average age was 40 years (range: 24 to 58), and 9 of 13 were male. Four of 13 employees reported working in other slaughter plants in the last 12 months, 2 as relief inspectors and 2 who were previously assigned to other poultry slaughter plants. Of 13 employees, 11 reported they were nonsmokers.

Of the 13 employees we interviewed, 9 reported itchy, watery eyes while at work during the past 12 months; 6 of these employees stated their symptoms improved when away from work on days off or on vacation. Three employees thought their symptoms were related to fluctuations in chlorine concentration on the processing line, because their symptoms occurred sporadically. One employee reported blurred vision at the end of the shift. Blurred vision, dry eyes, and eye irritation have been reported in NIOSH health hazard evaluations in other poultry processing plants [NIOSH 2012]. Of 13 employees, 7 reported sneezing and runny nose not related to a cold or flu in the past 12 months while at work; this improved on days away from work for 4 employees. Employees felt their nasal symptoms were related to fan use and ventilation issues, seasonal allergies, and chlorine exposure. Two employees reported taking medications for seasonal allergies and hay fever. Two employees reported a history of bronchitis or asthma in the past 12 months that began while working at the plant and improved on days off. Neither employee reported ever smoking cigarettes. Skin rash/dermatitis was reported by two employees who thought the cause was exposure to disinfectant chemicals and contact with chicken carcasses; symptoms improved when employees wore long sleeves that prevented contact with carcasses.

Communication and Work Organization

We asked employees about workplace communication (communication between USDA/FSIS onsite managers and employees, employees and the union, USDA/FSIS onsite managers and the union, and USDA/FSIS headquarters staff and employees). Two employees felt they could not comment on these questions due to the short period of time they had worked at the plant. One employee reported concerns about communication between employees and USDA/FSIS headquarters. Two employees reported communication concerns between FSIS plant managers and employees, the union and employees, and FSIS plant managers and the union. Four employees reported concerns about workload and production speed, specifically regarding the speed at which they were required to visually inspect bird carcasses. No one expressed concerns about scheduling, overtime, or interpersonal relationships with coworkers. Two employees expressed concerns about job security. Several employees stated that three or four employees who previously reported eye irritation, sore throat, and headache on the night shift no longer worked at the plant, and that modifications made to the plant's ventilation system over the past year to address condensation issues above the chiller tanks had led to an overall decrease in odors and complaints.

USDA/FSIS CA-1 Report Review

We reviewed summary information from the plant's CA-1 reports for the years 2010–2016. There were 18 reports for both inspection shifts at the plant. Slips, trips, and falls accounted for 11 reports; most were attributed to wet or icy floors. Cuts and bruises accounted for three reports, eye irritation from fecal material or chemicals accounted for three reports, and muscle strain accounted for one report.

Air Sampling

The four personal air samples collected on four USDA/FSIS inspectors during the second shift had detectable concentrations of acetic acid ranging from 0.045 ppm to 0.078 ppm. These concentrations were below OELs (Table 1). Full-shift peracetic acid exposures, collected on two inspectors during the second shift, were estimated to be 0.092 ppm and 0.0080 ppm, and full-shift hydrogen peroxide exposures were estimated to be 0.027 ppm and 0.0028 ppm (Table 1). These values are considered estimates since some of the short-term sample concentrations were below the MDC. These hydrogen peroxide levels were below applicable OELs.

Table 1. Concentrations of disinfection chemicals in full-shift personal air samples from second shift employees in the evisceration department

Job title	Sample duration (minutes)	Peracetic acid (ppm)*	Hydrogen peroxide (ppm)†	Acetic acid (ppm)‡
Inspector 1	497	—	—	0.050
Inspector 2	507	—	—	[0.045]§
Inspector 3	505	—	—	[0.047]
Inspector 4	507	—	—	0.078
Inspector 5	403	[0.0092]	[0.027]	—
Inspector 6	386	[0.0080]	[0.028]	—
NIOSH REL		NA	1	10
OSHA PEL		NA	1	10
ACGIH TLV		NA	1	10

ACGIH TLV = American Conference of Governmental Industrial Hygienists threshold limit value

MQC = Minimum quantifiable concentration

ND = Not detected

NA = Not applicable

PEL = Permissible exposure limit

REL = Recommended exposure limit

*The MDC of peracetic acid was 0.005 ppm, and the MQC was 0.026 ppm using an average sample volume of 15 liters.

†The MDC of hydrogen peroxide was 0.02 ppm, and the MQC was 0.064 ppm using an average sample volume of 15 liters.

‡ The MDC of acetic acid was 0.008 ppm, and the MQC was 0.048 ppm using an average sample volume of 51 liters.

§Concentration in brackets are between the MDC and MQC so there is more uncertainty associated with them.

The short-term personal air sample results for peracetic acid and hydrogen peroxide collected on two inspectors during the second shift are presented in Tables A1 (Inspector 5) and A2 (Inspector 6) in Appendix A. The two inspectors' short-term peracetic acid exposures ranged from 0.006 ppm to 0.019 ppm. These exposures were below applicable short-term exposure limits (STELs). Their short-term hydrogen peroxide exposures ranged from not detected to 0.022 ppm. Hydrogen peroxide does not have any STELs.

Short-term personal air samples for peracetic acid and hydrogen peroxide collected on three inspectors during the first shift are presented in Table A3. Short-term peracetic acid exposures were low (estimated as 0.0082 ppm, 0.0084 ppm, and 0.0087 ppm). Hydrogen peroxide was not detected in these samples. Although the analytical method may underestimate exposures when peracetic acid is applied as a spray [Hecht et al. 2004], we did not observe sprays, droplets, or aerosolization of the solution in the work areas where we collected air samples for peracetic acid and hydrogen peroxide. Therefore, these results should provide a good approximation of exposures.

Observations

About a year before this site visit, the plant installed a new ventilation system. The ventilation system was designed as a one-pass system with 100% outside air (no recirculation). The system provided heating or cooling depending upon plant conditions. Outdoor air was introduced into the southwest side of the building at the end of the production area. Air was exhausted from the building using three large rooftop fans in the scalding area, next to the ventilation room and live-hang area. The ventilation system filtered outside air entering the building using a two filter bank system with prefilters having a minimum efficiency reporting value of 10 and secondary filters with a minimum efficiency reporting value of 15. The filters were checked weekly and replaced as needed. The air flowed from clean areas to dirty areas, as is desired. The ventilation system had a dehumidifier that drained outside the main building.

We observed that employees wore the USDA/FSIS required personal protective equipment. Some employees wore latex gloves. Natural rubber latex can cause irritant contact dermatitis, allergic contact dermatitis, and immediate hypersensitivity [NIOSH 1997]. Because of the severity of symptoms that sensitized individuals may experience, non-latex gloves should be used.

Conclusions

The plant made several positive changes to the workplace environment between the time the HHE request was submitted and our visit, including installation of a new ventilation system and separation of the peracetic waste stream from the chlorine waste stream. We found low concentrations of acetic acid, peracetic acid, and hydrogen peroxide in personal air samples taken on inspectors in the evisceration area. All of the concentrations we measured in personal air samples were well below OELs, where applicable. Some employees reported occasional symptoms of eye irritation and nasal symptoms they thought were worse while at work. Although these symptoms can be caused by exposure to peracetic acid, acetic acid, hydrogen peroxide, and chlorine and chlorine byproducts, symptoms caused by these exposures are typically reported at concentrations much higher than we measured during our evaluation. Most employees felt that workplace conditions and communication had improved over the last year.

Recommendations

On the basis of our findings, we recommend the actions listed below. We encourage USDA/FSIS to use a labor-management health and safety committee or working group to discuss our recommendations and develop an action plan. Those involved in the work can best set priorities and assess the feasibility of our recommendations for the specific situation at the poultry plant. We encourage USDA/FSIS to also work with plant management to address recommendations that involve ventilation and chemical handling. NIOSH has a webpage for the poultry industry that contains recommendations to address exposure and health concerns that can arise from the use of disinfectants (https://www.cdc.gov/niosh/topics/poultry/evaluating.html).

Our recommendations are based on an approach known as the hierarchy of controls (Appendix B: Occupational Exposure Limits and Health Effects). This approach groups actions by their likely effectiveness in reducing or removing hazards. In most cases, the preferred approach is to eliminate hazardous materials or processes and install engineering controls to reduce exposure or shield employees. Until such controls are in place, or if they are not effective or feasible, administrative measures and personal protective equipment may be needed.

Administrative Controls

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

1. Encourage USDA/FSIS inspectors to continue reporting symptoms they experience to their supervisor and occupational safety and health specialists at USDA. Reporting allows for investigation of the specific conditions present when symptom frequency increases.
2. Periodically and after incidents and near-misses, provide refresher training on the prevention of slips, trips, and falls for inspectors. Training should be in accordance with OSHA's general industry walking-working surfaces and fall protection standard. OSHA has developed training specifically for the poultry industry available at https://www.osha.gov/dte/grant_materials/fy11/sh-22311-11/TrainersGuide.pdf.

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 may be needed. Personal protective equipment should not be the sole method for controlling hazardous exposures. Rather, personal protective equipment should be used until effective engineering and administrative controls are in place.

1. Provide nitrile gloves instead of natural rubber latex gloves to protect employees' skin from dermal exposures. Train employees on proper glove wear and on visual signs that the glove material is worn out, so that they recognize when they need new gloves. Additional information on the occupational hazards associated with latex exposure can be found in the NIOSH Alert *Preventing Allergic Reactions to Natural Rubber Latex in the Workplace*, available at http://www.cdc.gov/niosh/docs/97-135/.

Appendix A: Tables

Table A1. Short-term breathing zone air sample concentration results for peracetic acid and hydrogen peroxide for Inspector 5

Sample duration (minutes)	Peracetic acid* (ppm)	Hydrogen peroxide† (ppm)
19	[0.011]‡	[0.017]
15	[0.009]	ND
16	[0.010]	ND
14	[0.011]	[0.024]
15	[0.011]	ND
17	[0.007]	ND
17	[0.008]	ND
17	[0.012]	ND
15	[0.012]	ND
15	[0.013]	ND
15	[0.008]	ND
15	[0.005]	ND
18	[0.008]	ND
15	[0.010]	ND
16	[0.009]	ND
23	[0.008]	ND
16	[0.011]	ND
16	[0.009]	ND
15	[0.009]	ND
16	[0.011]	ND
15	[0.011]	ND
15	[0.007]	ND
16	[0.005]	ND
16	[0.008]	ND
16	[0.009]	ND
NIOSH REL	NA	§
OSHA PEL	NA	§
ACGIH TLV	0.4 (STEL)¶	§

*The MDC of peracetic acid was 0.005 ppm, and the MQC was 0.026 ppm using an average sample volume of 15 liters.

†The MDC of hydrogen peroxide was 0.02 ppm, and the MQC was 0.064 ppm using an average sample volume of 15 liters.

‡Concentrations in brackets are between the MDC and MQC.

§TWA – No STEL established. The full-shift 8-hour TWA exposure limit is 1 ppm.

¶STEL – 15-minute sampling period applicable to peracetic acid air samples

Table A2. Short-term breathing zone air sample concentration results for peracetic acid and hydrogen peroxide for Inspector 6

Sample duration (minutes)	Peracetic acid* (ppm)	Hydrogen peroxide† (ppm)
18	[0.010]‡	ND
14	[0.007]	ND
15	[0.007]	[0.022]
16	[0.007]	ND
18	[0.008]	ND
15	[0.005]	ND
18	[0.013]	ND
14	[0.019]	[0.024]
15	[0.013]	ND
15	[0.010]	ND
15	[0.006]	ND
18	[0.006]	ND
15	[0.008]	ND
16	[0.007]	ND
22	[0.009]	ND
17	[0.008]	[0.019]
17	[0.007]	ND
15	[0.008]	ND
16	[0.007]	ND
15	[0.006]	ND
15	[0.005]	ND
16	[0.006]	ND
15	[0.007]	ND
16	[0.005]	ND
NIOSH REL	NA	§
OSHA PEL	NA	§
ACGIH TLV	0.4 (STEL)¶	§

*The MDC of peracetic acid was 0.005 ppm, and the MQC was 0.026 ppm using an average sample volume of 15 liters.

†The MDC of hydrogen peroxide was 0.02 ppm, and the MQC was 0.064 ppm using an average sample volume of 15 liters.

‡Concentration in brackets are between the MDC and MQC.

§TWA – No STEL established. The full-shift 8-hour TWA exposure limit is 1 ppm.

¶STEL – 15-minute sampling period applicable to peracetic acid air samples

Table A3. Concentrations of disinfection chemicals in short-term, personal air samples from employees on the first shift in the evisceration department

Job title	Sample duration (minutes)	Peracetic acid (ppm)*	Hydrogen peroxide (ppm)†
Inspector 7	15	[0.0082]‡	ND
Inspector 8	15	[0.0087]	ND
Inspector 9	15	[0.0084]	ND
NIOSH REL		NA	§
OSHA PEL		NA	§
ACGIH TLV		0.4 (STEL)¶	§

*The MDC of peracetic acid was 0.005 ppm, and the MQC was 0.026 ppm using an average sample volume of 15 liters.

†The MDC of hydrogen peroxide was 0.02 ppm, and the MQC was 0.064 ppm using an average sample volume of 15 liters.

‡Concentration in brackets are between the MDC and MQC.

§TWA – No STEL established. The full-shift 8-hour TWA exposure limit is 1 ppm.

¶STEL – 15-minute sampling period applicable to peracetic acid air samples

Appendix B: Occupational Exposure Limits and Health Effects

NIOSH investigators refer to mandatory (legally enforceable) and recommended OELs for chemical, physical, and biological agents when evaluating workplace hazards. OELs have been developed by federal agencies and safety and health organizations to prevent 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 pre-existing 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 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 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.

- The U.S. Department of Labor OSHA PELs (29 CFR 1910 [general industry]; 29 CFR 1926 [construction industry]; and 29 CFR 1917 [maritime industry]) are legal limits. These limits are enforceable in workplaces covered under the Occupational Safety and Health Act of 1970.
- NIOSH 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 2010]. 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 is the ACGIH TLVs. The 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 2017].

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, available at http://www.dguv.de/ifa/GESTIS/GESTIS-Internationale-Grenzwerte-für-chemische-Substanzen-limit-values-for-chemical-agents/index-2.jsp, contains international limits for more than 2,000 hazardous substances and is updated periodically.

OSHA 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 [Occupational Safety and Health Act of 1970 (Public Law 91–596, sec. 5(a)(1))]. 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. NIOSH investigators also encourage use of the hierarchy of controls approach to eliminate or minimize workplace hazards. This includes, in order of preference, the use of (1) substitution or elimination of the hazardous agent, (2) engineering controls (e.g., local exhaust ventilation, process enclosure, dilution ventilation), (3) administrative controls (e.g., limiting time of exposure, employee training, work practice changes, medical surveillance), and (4) personal protective equipment (e.g., respiratory protection, gloves, eye protection, hearing protection). Control banding, a qualitative risk assessment and risk management tool, is a complementary approach to protecting employee health. Control banding focuses on how broad categories of risk should be managed. Information on control banding is available at http://www.cdc.gov/niosh/topics/ctrlbanding/. This approach can be applied in situations where OELs have not been established or can be used to supplement existing OELs.

Peracetic Acid

Peracetic acid is used as a disinfectant in the biotechnology, food, healthcare, and pharmaceutical industries. Pechacek et al. [2015] estimated that in 2004, less than 20,000 tons of peracetic acid was used in the United States; however, usage in the United States has increased since then. According to the Environmental Protection Agency ChemView database, in 2015, it is estimated that 5,000,000–25,000,000 tons of peracetic acid was produced in the United States [EPA 2017]. Peracetic acid may be present in particle and vapor phases, especially during spraying or fogging [ACGIH 2001]. ACGIH has established a TLV-STEL of 0.4 ppm for peracetic acid measured as an inhalable fraction and vapor [ACGIH 2017]. Neither NIOSH nor OSHA has established OELs for peracetic acid. Peracetic acid is volatile and has a pungent, vinegar-like odor. An unpublished Swedish report estimated the odor threshold as 0.05 ppm [Pechacek et al. 2015]. An acute exposure guideline of 0.17 ppm was recommended as a threshold for irritation in the general population [National Academies Press 2010]. Peracetic acid is considered to be a stronger sensory irritant than acetic acid or hydrogen peroxide [National Academies Press 2010].

Asthma associated with peracetic acid exposure in healthcare workers has been reported [Cristofari-Marquand et al. 2007].

In 2006, the Health Hazard Evaluation Program evaluated exposure to a peracetic acid-containing sterilant in a hospital endoscopy reprocessing department [NIOSH 2009]. The concentrated sterilant was used in automated endoscopy reprocessing machines that occasionally malfunctioned; some employees reported headache, burning eyes, and skin burns that were more common during machine malfunction or when handling the concentrate without appropriate personal protective equipment. Most reported adverse events from exposure to the sterilant were skin burns from exposure to the concentrated solution; however, shortness of breath and nasal irritation were also reported. In 2014, the Health Hazard Evaluation Program evaluated exposures to peracetic acid, hydrogen peroxide, and acetic acid for USDA/FSIS inspectors in a poultry processing plant [NIOSH 2016]. Peracetic acid was not detected in the personal air samples. Low concentrations of acetic acid and hydrogen peroxide were found in the evisceration department and surrounding areas. Some employees reported occasional eye and throat irritation. In another health hazard evaluation, NIOSH investigators found symptoms of watery eyes, nasal problems, asthma-like symptoms, and shortness of breath among employees working with peracetic acid disinfectant in a hospital [Hawley et al. 2016; NIOSH 2017].

Acetic Acid

Acetic acid 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. The odor threshold for acetic acid is typically 24 ppm. Acetic acid solution contact with eyes and skin can cause eye damage and skin irritation. Dilute acetic acid solutions have a low vapor pressure, which results in low inhalation exposures [ACGIH 2001]. NIOSH and OSHA have established OELs of 10 ppm [NIOSH 2010]. ACGIH has established a TLV of 10 ppm and a TLV-STEL of 15 ppm for acetic acid [ACGIH 2017]. Acetic acid has not been shown to cause cancer in animal studies.

Hydrogen Peroxide

The OELs for hydrogen peroxide are based on the potential irritating effects to the eyes, skin, mucous membranes, and respiratory tract. NIOSH, OSHA, and ACGIH have established OELs of 1 ppm for hydrogen peroxide, as 8-hour TWAs [ACGIH 2017; NIOSH 2010]. A case report described diffuse interstitial lung disease and shortness of breath in a dairy plant worker exposed to hydrogen peroxide while operating a milk packing machine that used a hydrogen peroxide bath to disinfect milk cartons [Kaelin et al. 1988]. Hydrogen peroxide air concentrations were approximately 30 ppm near the machine and 9 ppm close to the floor, both well above OELs. All seven employees who worked in the milk packing department reported eye and throat irritation and the gradual bleaching of their hair. The one employee with shortness of breath reported that symptoms improved without treatment 1.5 months after removal from exposure. A study among workers at a beverage processing plant where bottles were disinfected with a solution of hydrogen peroxide, acetic acid, and peracetic acid showed no significant changes in lung function over time at levels at or below the hydrogen peroxide

OEL of 1 ppm [Mastrangelo et al. 2005]. ACGIH lists hydrogen peroxide as a "confirmed animal carcinogen with unknown relevance to humans" [ACGIH 2001]. No other agency has listed hydrogen peroxide as a carcinogen.

Chloramines

Chloramines, specifically trichloramine and soluble chlorine compounds, are inorganic compounds formed by the reaction between chlorine disinfectants and nitrogenous compounds such as ammonia, amines, or organic nitrogen-containing material. The species and concentrations of chloramine are influenced by the concentration of residual chlorine, ammonia (or other nitrogen sources), pH, and temperature. In general, the lower the pH and the greater the chlorine to ammonia ratio, the higher the likelihood of producing trichloramine. No OELs for chloramines have been established. We did not evaluate levels of chloramines in air, which are also associated with irritative symptoms, because current analytical methods do not provide reliable results (https://www.cdc.gov/niosh/topics/poultry/evaluating.html).

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