Health Hazard Evaluation Program

Evaluation of Ergonomics, Chemical Exposures, and Ventilation at Four Nail Salons

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Authors: **Kendra Broadwater, MPH, CIH**

Sophia Chiu, MD, MPH

Analytical Support: Maxxam Laboratories

Desktop Publisher: Jennifer Tyrawski

Editor: Cheryl Hamilton

Industrial Hygiene Field Assistance: Michael Grant, Jessica Ramsey, Dylan Neu

Logistics: Donnie Booher, Kevin Moore

Medical Field Assistance: Kerton Victory

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Disclaimer

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Availability of Report

Copies of this report have been sent to the employers and employees at the nail salons. The state and local health department and the Occupational Safety and Health Administration Regional Office have also received a copy.

Recommended Citation

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Introduction

Request

A state health department requested help from the National Institute for Occupational Safety and Health (NIOSH) because of concerns about chemical exposures and musculoskeletal disorders among nail salon employees.

Workplace

Nail salon technicians provided nail services, including applying, removing, filling, and polishing acrylic nails and providing standard polish, gel and shellac polish manicures and pedicures. Gel and shellac manicures and pedicures involve polishes that are cured using ultraviolet lamps. Some technicians also provided hair removal waxing services. From 3 to 11 employees worked at each of the four salons.

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

Our Approach

We visited four nail salons to learn more about chemical and particulate exposures and the work-related health concerns of their technicians. We visited Salons A and B in August 2015. We visited Salon B again in March 2016. We visited Salon C in October 2016 and Salon D in November 2016.

On the visits, we

- Observed work practices and conditions
- Inspected shop ventilation
- Measured employee exposures to volatile organic compounds in the air such as acetone, toluene, n-butyl acetate, ethyl acetate, formaldehyde, methyl methacrylate, and ethyl methacrylate
- Interviewed employees about their work and health

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

Our Key Findings

Employees worked in positions that posed risks for developing musculoskeletal disorders.

- We observed employees repeatedly bending their necks and shoulders during nail services in ways that might cause injury or pain (Figure 1).

Figure 1. Two employees providing pedicures to clients. The left employee's shoulders are hunched forward and her back rounded. The right employee's back is unsupported by the low chair back and her neck is bent forward and straining at the shoulder. Photos by NIOSH.

- We observed seated employees repeatedly lift and hold clients' feet during pedicures to shoulder height during callus removal. This practice can put stress on employees' upper back and shoulders.
- We found 4 of the 19 employees (21%) who had worked in the nail salon for ≥ 2 months reported musculoskeletal pain (neck, shoulder, and upper back pain) that got better away from work.

Work practices and conditions contributed to chemical exposures from nail polish remover, nail polish, acrylic polymers, and powders.

- Chemical storage was inappropriate. For example, we saw chemicals stored in unlabeled containers, open containers, and areas that were also used as employee break and lunch rooms (Figures 2 and 3). One salon employee stored bulk chemicals for the salon in a personal residence.

Figure 2. Nail salon products stored under a sink in Salon A. Most of the containers were not properly labeled with their contents. Powder was stored in a mislabeled container in the bottom right corner. Photo by NIOSH.

- Ten of 24 interviewed employees reported receiving training on chemical hazards since they began working at the salon.
- Nine of 10 nail salon technicians observed (Salons B–D) performing pedicures wore gloves while providing the service, but several technicians took gloves off for nail polish application. We observed all nail salon technicians remove nail polish from clients' skin using bare fingers.
- Five of 14 nail salon technicians observed (Salons B–D) performing manicures (acrylic, dip acrylic, gel, or standard) wore nitrile or latex gloves at some point while providing the service. Some of these employees only wore gloves during nail polish removal or while shaping the acrylic nail using a powered rotary filing tool.
- Employees we observed wore N95 respirators incorrectly. Employees also wore other masks that would not adequately protect against respiratory hazards in the salons, like acrylic particulate.
- Personal exposures to formaldehyde in air exceeded the NIOSH occupational exposure limit in each of the salons where we took personal measurements. However, overexposures to formaldehyde can occur in many common indoor environments and may not necessarily be due to salon product exposure.
- Personal exposures to acetone in the air at Salon C were much higher than exposures measured in the other salons we assessed and in other nail salon studies.
- Total particulate concentrations at Salons C and D were higher near acrylic nail stations where employees used powered rotary filing tools to shape acrylic nails, as opposed to locations located 3 or more meters away from the stations (Figure 4).

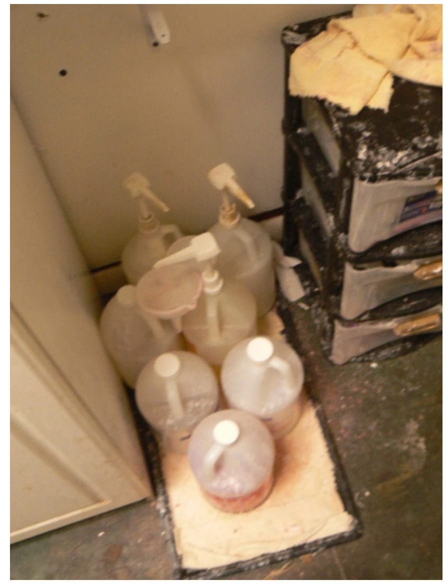


Figure 3. New and used chemical bottles (acetone, isopropyl alcohol, and cuticle softener) stored in the break room in Salon C. Above these bottles was a shelf where bowls containing acetone were put to dry. Photo by NIOSH.

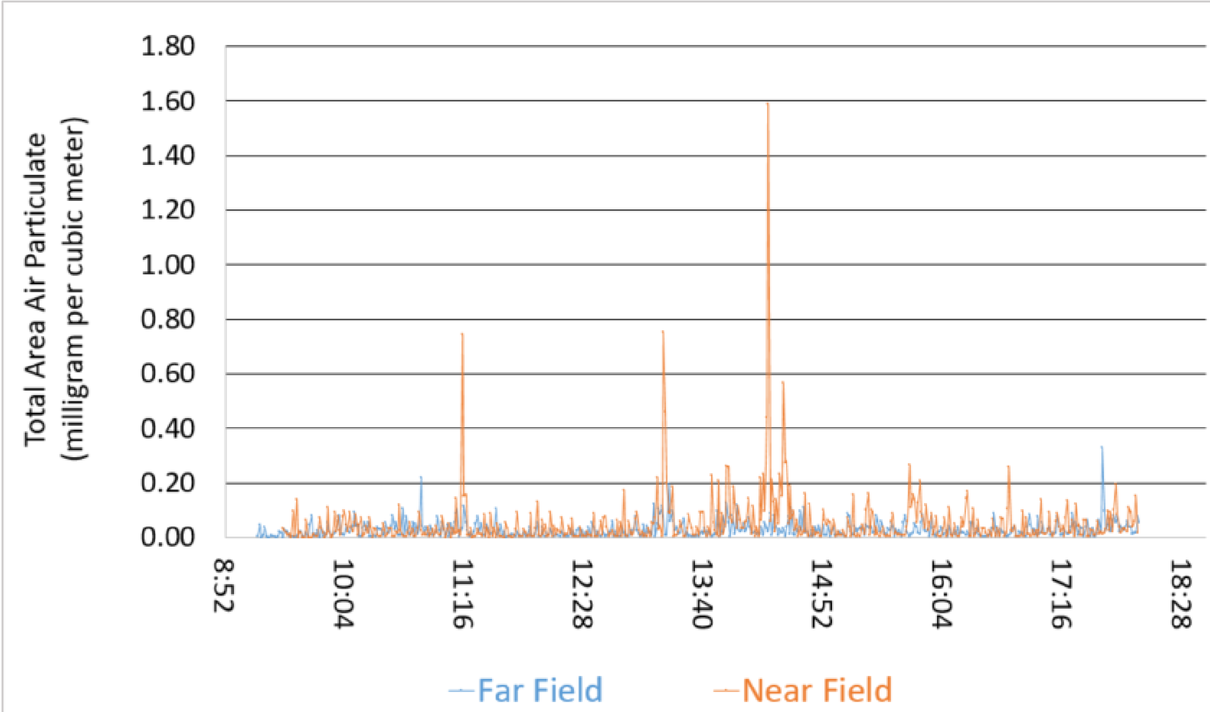


Figure 4. The orange line shows total area air particulate concentrations near the acrylic nail application station in Salon C. The blue line shows total area air particulate concentrations at least 3 meters from the acrylic nail application station. The boxed area indicates peaks of particulate concentrations near a powder acrylic nail application (called the dip system) at the acrylic nail station.

Ventilation systems at the salons did not meet ventilation guidelines.

- Salon A did not have mechanical ventilation, relying on an open door for outdoor air introduction. A mini split ductless unit was used for heating and cooling.
- Salons B and C each had one roof fan that exhausted indoor air from vents located in the shop ceiling. Supply air came from doors and windows. Salon B had two in-wall air cooling units. Salon C had one in-wall air cooling unit.
- Salon D appeared to have a general ventilation system and a small direct exhaust system, but the systems were not operating at the time of our visit.
- None of the salons had local exhaust ventilation at acrylic nail or manicure stations.

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

Our Recommendations

The Occupational Safety and Health Act requires employers to provide a safe workplace.

Benefits of Improving Workplace Health and Safety:

- ↑ Improved worker health and well-being
- ↑ Better workplace morale
- ↑ Better employee recruiting and retention
- ↑ Improved image and reputation
- ↑ Better products, processes, and services
- ↑ Could increase overall cost savings

The recommendations below are based on the findings of our evaluation. 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 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 might be needed. Read more about the hierarchy of controls: https://www.cdc.gov/niosh/topics/hierarchy/.

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 *Recommended Practices for Safety and Health Programs*: https://www.osha.gov/shpguidelines/index.html.

Recommendation 1: Improve ergonomics during work tasks.

Why? Awkward work postures, repetitive or fast work, and high force can result in musculoskeletal pain and disorders. These conditions can worsen over time and are associated with

- Increased use of sick leave
- Lower productivity
- Lower employee morale
- Lower quality of life

Studies have found that musculoskeletal symptoms are more common among nail salon workers than office workers. At all four salons, we observed employees working in awkward postures. Some employees reported musculoskeletal pain that got better away from work.

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

Raise the existing client pedicure chairs. When buying new chairs, choose client pedicure chairs that are tall enough for employees to comfortably work on clients' feet.

- Reduce the distance that employees need to lift clients' legs when removing callused skin.
- Reduce the amount of employee neck and back bending needed to see clients' feet and toenails.

Provide stationary magnifying glasses at work stations or safety glasses with magnifying lenses to employees to reduce the need to bend at the shoulders and neck to see the client's toenails or fingernails.

Provide adjustable manicure and pedicure chairs to employees so they can change their workstations to be more comfortable.

Train employees on good ergonomic postures during nail services when they are hired and at least every year afterwards.

- Bring clients' hands or feet up closer toward their faces to prevent increased bending at the neck and hunching the shoulders.
- Move the foot pedal for the powered rotary filing tool to a comfortable position in front of their bodies. Adjust the position of the foot pedal occasionally to remain comfortable and avoid repetitive strain.
- Adjust their chair/stool each time they move to a new workstation so that they are comfortable, have both feet on the ground, and can use the back rest while working. Adjust the height as often as necessary to remain comfortable throughout the day.
- Place a pad on their side of the manicure workstation under their elbows or forearms to prevent sharp table corners from pressing into their arms. Learn more about reducing ergonomic hazards through the Occupational Safety and Health Administration (OSHA) document *Stay Healthy and Safe While Giving Manicures and Pedicures: A Guide for Nail Salon Workers*. It is available at https://www.osha.gov/SLTC/nailsalons/.

Recommendation 2: Improve work practices, conditions, and training to reduce employee contact with nail salon chemicals.

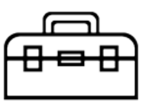
Why? Some chemicals used in nail salons can be inhaled through the lungs or absorbed through the skin. Depending on exposure, some chemicals in nail salon products can cause health problems like

- Skin rash or contact dermatitis
- Eye, nose, throat irritation
- Asthma
- Neurological effects
- Reproductive problems
- Cancer

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

Make sure products used in the nail salon do not include methyl methacrylate monomer.

- Use safety data sheets to find out which ingredients are in products used in the salon.
- Follow local and state rules regarding nail salon products. Methacrylate monomer is not allowed to be sold in the state where these salons were located, but one of the salons we evaluated used a liquid containing essentially all methyl methacrylate monomer.



Use pressure-activated liquid product dispensers to limit the potential for spills.

- Use dispensers that are designed to reduce the risk of spills for common nail salon products, such as acetone and isopropyl alcohol.
- Pressure from a cotton ball or brush is needed to dispense product from these containers, which remain closed when not in use. This reduces evaporation of the product into the air.

Inform employees of the chemicals they are working with and their potential for causing health problems.

Fulfill the requirements of the OSHA Hazard Communication Standard (CFR 1910.1200):

- Train employees on the hazards of the chemicals used in the salon.
  - Replace outdated material safety data sheets with safety data sheets that meet the current OSHA Hazard Communication Standard.

- Ensure that employees know where safety data sheets for products are kept.
- Label all secondary containers that contain hazardous substances with their contents (e.g., if moved from the original container).
- Find more information about specific hazard communication requirements at https://www.osha.gov/dsg/hazcom/index.html.

Do not store chemicals in employee break areas or at home.

- Use a separate, well-ventilated area to store chemicals away from workers.
- Do not store chemicals in open containers when they are not in use. Keeping containers closed prevents chemicals from evaporating and entering the air.

Do not leave acetone in open bowls or containers to evaporate in the workplace and do not heat acetone.

- Keeping chemical containers open can lead to higher than expected concentrations of volatile chemicals in the air. This is especially true when the storage space is unventilated.
- Wrap acetone-moistened cotton around clients' nails for polish or gel manicure removal, rather than having clients soak their fingers in bowls of acetone.

Reduce employees' skin exposure to chemicals when they provide nail services or handle nail salon products.

- Encourage employees to use tools and not bare fingers when applying acrylic nails and nail polish and when correcting polish mistakes. For example, a water-moistened cotton swab can be used to remove small amounts of wet nail polish from clients' skin instead of bare fingers.
- Train employees to practice good hand hygiene. This includes washing hands often, particularly:
  - Whenever chemicals or nail salon products are on their skin
  - Before breaks, eating, and leaving work
  - After removing gloves and after cleaning their workstation or the salon
- Instruct employees to wear gloves to prevent skin exposure to chemicals. Nitrile gloves can protect against many chemicals used in the salon.
- Provide butyl gloves for employees' use when they directly handle acetone, such as when transferring acetone between bottles, pouring acetone into the waste acetone container, and cleaning up acetone spills. Nitrile gloves might not hold up well against acetone and wearing natural rubber latex gloves can cause allergies.

Encourage employees to report any work-related symptoms to their supervisor or the nail salon owner and to their primary health care provider.

Train employees who voluntarily wear N95 respirators about their use.

- Provide training to these employees on how to wear N95 respirators correctly.
- Inform employees that N95 respirators do not protect against exposures to gases or vapors. They do protect against dusts created during tasks like shaping acrylic nails with the handheld powered rotary filing tool, applying powder during dip acrylic nail application, and filing natural nails.
- Review and share this respirator training tool available at http://www.cdc.gov/niosh/docs/2010-133/pdfs/2010-133.pdf.
- Give employees who voluntarily wear N95 respirators a copy of the OSHA Respiratory Protection Standard 1910.134 Appendix D. It is available at https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9784.

Provide employees with splash-resistant eye protection, like goggles, to use when they refill liquid chemical containers.

Recommendation 3: Improve ventilation to reduce airborne levels of chemicals from nail salon products and improve indoor air quality.

Why? Chemicals in nail salon products can get into the body by breathing in their dusts and vapors. Although employees' airborne exposures to most chemicals we measured did not exceed occupational exposure limits, improving ventilation will further reduce air levels. Introducing outdoor air into the shop can help reduce formaldehyde concentrations. Reducing and preventing exposures can reduce health risks associated with these exposures.

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

Make sure that the ventilation system provides a source of filtered outdoor air when the salon is occupied. It should meet the ASHRAE standards for ventilation and thermal comfort.

- Work with a ventilation engineer to develop plans for a mechanical ventilation system that meets these requirements.

- ASHRAE recommends supplying at least 20 cubic feet per minute of outdoor air to the workplace for each occupant, including both employees and customers.

Ensure that the existing ventilation system is on and working during business hours. Work with building maintenance staff to do so if the nail salon is in a leased space.

Use local exhaust ventilation to reduce acrylic dust and chemical exposures in air.

- Local exhaust ventilation can reduce chemical and dust exposures in the air during nail services. It comes in many forms: portable units that filter or exhaust air to the outdoors, manicure tables with integrated ventilation, and more.
- Use local exhaust ventilation that was designed for use in nail salons and evaluated for effectiveness. Small tabletop filters or fans are not designed to reduce employees' chemical and dust exposures.
- Reduce the impact of the noise generated by the fan motors by housing the fans farther from the workstation and insulating the fan and motor.
- Establish a maintenance plan to ensure that ventilation systems remain effective.

Supporting Technical Information

Evaluation of Ergonomics, Chemical Exposures, and Ventilation at Four Nail Salons

HHE Report No. 2015-0139-3338

March 2019

Section A: Workplace Information

Building and Business Information

Salon A:

- Shop at the ground floor of a six-story building in a dense urban neighborhood
- No ducted ventilation system
- A mini split ductless unit for heating and cooling
- One exterior door at the front of the shop

Salon B:

- Single-story, multi-tenant building with one main salon room in a dense urban neighborhood
- Exhaust vents along the salon ceiling centerline served by one roof exhaust fan
- Air conditioning units on the exterior wall without outdoor air introduction

Salon C:

- Standalone building with the nail salon as the single business occupant in an urban neighborhood
- Exhaust vents throughout the salon floor centerline served by one roof exhaust fan
- Baseboard radiant heating system and air conditioning units located on exterior wall without outdoor air introduction

Salon D:

- Shop on the second floor of an indoor shopping mall
- Front entrance was open to the common walkway of the mall during working hours
- Shop served by the mall's air handling units with supply and return grilles on or near the ceiling. The shop also had two exhaust vents on or near ceiling.

Employee Information

- Number of employees at time of evaluation: 24 (total)
    - Salon A: 5 employees
    - Salon B: 11 employees
    - Salon C: 3 employees
    - Salon D: 5 employees

- Reported length of shift: varies, 2–8 hours
- Median number of hours worked per week: 30 hours (range: 12–60 hours)
- Median job tenure: 9 months (range: 1 week–21 years). Six employees at one salon reported working there for only 1 week.
- Median age of employees: 36.5 years (range: 22–56 years)
- Sex: 88% female
- Race/ethnicity: 15 employees identified as Asian (Vietnamese); 9 employees identified as Hispanic
- Additional information: All 24 employees participated in confidential interviews: 23 in person during site visits and 1 by phone. One employee communicated solely in English during the site visit. Interpreters in Spanish and Vietnamese allowed us to communicate with the other employees.

Background about the Request

A state health department was asked to provide feedback to elected state officials about health effects and possible exposures associated with nail salon work. The state health department requested help from NIOSH in their evaluation of the health implications of working as a nail salon technician. The specific concerns were chemical and particulate exposures in the air and on the skin, and ergonomics during nail salon work. The state health department and NIOSH reached out to salons to participate in the evaluations. No specific health issues were identified at any salon before the evaluations.

Process Description

The nail salon technicians at these salons provided a variety of services:

Acrylic nails: application, fill, and removal. Standard acrylic nails were created when acrylic monomer liquid was mixed with acrylic polymer powders and applied to the natural nail (with or without a nail extension). The acrylic was shaped using a small brush when still curing and shaped further using a handheld powered rotary filing tool to make the final nail shape after the acrylic had hardened. Then the nail was cleaned and painted using standard or gel polish. The dip acrylic nail manicure involved alternating layers of cyanoacrylate nail glue and finely milled methacrylate polymer powder on the natural nail with an extension. The nail was either dipped into or sprinkled with the powder. These layers were repeated several times to create a strong acrylic nail. The copolymer typically was pigmented and the nail did not need further colored polish.

Manicures and pedicures: during manicures and pedicures, technicians used hand tools to trim and shape the natural nail. Products used during this service included nail polish remover, disinfectants, rubbing alcohol, lotions and moisturizers, callus remover or softener, colored nail polishes, and clear coats. Gel and shellac manicures and pedicures involved polish cured using ultraviolet light into a hard, shiny coating. This coating was generally removed by soaking in acetone.

Technicians at three of the salons (B, C, and D) also provided waxing hair removal services.

Section B: Methods, Results, and Discussion

Our objectives were to

- Identify and measure personal exposures in the air to chemicals in nail salon products
- Evaluate dermal exposures to nail salon products
- Evaluate job task ergonomics and determine if they could contribute to musculoskeletal disorders
- Understand how the salons are ventilated
- Determine the prevalence of illnesses or health symptoms that might be related to chemical exposures or ergonomic issues at each salon

We visited Salons A and B in August 2015. We visited Salon B again in March 2016. We visited Salon C in October 2016 and Salon D in November 2016.

Methods: Ergonomics Assessment

We collected information regarding ergonomics through (1) conducting confidential employee interviews, (2) observing employees perform nail services, and (3) assessing workplace design and equipment.

For confidential employee interviews,

- We invited all employees working during our site visits to participate.
- We asked employees about work history, work processes, and training.
- We conducted interviews in English or, with assistance from interpreters, in Vietnamese or Spanish.

While observing employees providing nail services, we evaluated employees' neck, arm, back, and leg positions. We assessed work positions to identify awkward positions, repetitive and high force tasks, and other characteristics that may contribute to musculoskeletal disorders or pain. We assessed how employees hold and work on clients' hands and feet and determined if those positions could be modified to encourage neutral neck, back, and leg positions for the employee.

Results: Ergonomics Assessment

Confidential Employee Interviews

Table C1 shows the services employees reported providing in the 4 weeks before the interview. Standard manicures and pedicures were the most commonly reported services, reported by 21 (88%) employees. Few employees reported working with customers who had open sores or cuts on their hands (n = 1) or feet (n = 2).

Four (21%) of the 19 employees who worked at the salon for at least 2 months reported musculoskeletal pain in the past 4 weeks. Two employees reported upper back pain that they stated was better away from work. One employee reported upper back and shoulder pain while performing pedicures; this pain reportedly improved away from work. One employee reported neck pain that worsened when looking down while performing manicures. This employee reported not having neck pain prior to working in the nail salon.

Observations

Across the salons, we observed good ergonomics practices among only a few employees, primarily at Salon C. During manicures, employees at Salon C positioned the customers' hands higher and closer to themselves to reduce bending at the neck and shoulders. Most employees' practices caused them to bend their necks forward excessively and hunch their shoulders during manicures and pedicures (Figure 1). We observed seated employees lift and hold clients' feet during pedicures to shoulder height during callus removal, stressing employees' upper back and shoulders.

Workplace factors contributed to poor ergonomics. These included nonadjustable work tables and chairs and a lack of magnification. For example, the low position of customers' feet when they sit in pedicure chairs made practicing good body position and work practices especially challenging. Employees had to lean over the clients' feet to view them closely, to scrub the legs and feet, and to shape and paint the clients' toenails. All salon stations were equipped with table lamps that employees could use to illuminate their workplace.

Methods: Chemical and Particulate Exposure

We gathered information about workers' exposure to nail salon chemicals through

- Measuring personal exposures to volatile organic compounds and other chemicals in air (Salons B–D)
- Measuring area air particulate concentrations
- Measuring chemicals in bulk nail polish and acrylic monomer liquid
- Observing dermal exposures during work
- Examining employees' hands for skin rash or irritation during site visits
- Interviewing employees about their health and work-related symptoms

We measured employees' personal air exposures to chemicals that are found in some nail polish and acrylic nail products. We compared air concentration sampling results to occupational exposure limits (OELs) developed by federal agencies, like NIOSH and OSHA, and safety and health organizations, such as the American Conference of Governmental Industrial Hygienists (ACGIH). These exposure limits are described in Section D.

- We collected full-shift personal air samples for toluene, acetone, n-butyl acetate, and ethyl acetate using charcoal sorbent tubes. Samples were collected and analyzed for toluene using NIOSH Method 1501, acetone using NIOSH Method 1300, and n-butyl acetate and ethyl acetate using NIOSH Method 1450 [NIOSH 2019]. Full-shift air samples were collected using pumps with a flow rate of 100 cubic centimeters per minute.

- We collected full-shift personal air samples for methyl methacrylate and ethyl methacrylate using XAD-2 solid sorbent tubes. Samples were collected and analyzed in accordance with NIOSH Method 2537 [NIOSH 2019]. Full-shift air samples were collected using pumps with a flow rate of 100 cubic centimeters per minute.
- We collected full-shift personal air samples for formaldehyde using SKC UMEx 100 passive badges. The full-shift air samples were collected and analyzed in accordance with OSHA Method 1007 [OSHA 2005].

Particulate was generated during acrylic nail application when handheld powered rotary filing tools were used to shape the nail. We measured particulate concentrations using TSI DustTrak direct reading instruments. We took air measurements close to acrylic nail work stations and at least 3 meters from acrylic nail work stations in Salons B–D. At Salons C and D, we measured the particulate concentrations simultaneously. At Salon B, the samples were taken on consecutive days.

We collected samples of used nail polish from Salons A and B to measure chemicals of interest ($n = 18$). We also sampled unused, new nail polishes that matched the brands and product names we collected from Salons A and B ($n = 14$). Four of the polishes we collected from the salons were not available for purchase.

We had these polishes analyzed for n-butyl acetate, ethyl acetate, toluene, formaldehyde, dibutyl phthalate, and triphenyl phosphate using the following techniques:

- Dibutyl phthalate, ethyl acetate, n-butyl acetate, toluene: gas chromatography with flame ionization detection
- Formaldehyde: liquid chromatography with ultraviolet detection
- Triphenyl phosphate: gas chromatography with flame photometric detection

We compared the concentrations of the analyzed components in used and unused nail polish samples using Student's paired t-test.

At Salons C and D, we collected samples of the methacrylate monomer liquid used to create acrylic nails. We analyzed these samples for ethyl methacrylate and methyl methacrylate using gas chromatography with flame ionization detection.

At all four salons, we assessed employee glove use while providing nail services. In Salons C and D, we also examined employees' hands for skin rash or irritation.

During the confidential interviews ($n = 24$), we asked employees about their medical history and health symptoms. Respiratory, irritant, and skin symptoms were defined as work-related if they improved after being away from work for more than one day.

Results: Chemical and Particulate Exposure

Personal Air Exposures for Acetone, Toluene, n-Butyl Acetate, Ethyl Acetate, Formaldehyde, Methyl Methacrylate, and Ethyl Methacrylate at Salons B–D

Summary personal air sampling results for volatile organic compounds and methyl and ethyl methacrylates are presented in Table C2. The personal air sampling results, summarized by salon, are presented in Table C3. We used the limit of detection divided by the square root of 2 to impute a value when the compound was not detected [Hornung and Reed 1990]. We measured personal formaldehyde concentrations above the NIOSH recommended exposure limit (REL) of 0.016 parts per million (ppm) in 6 of 24 full shift measurements in Salons B–D. Concentrations ranged from 0.005 to 0.02 ppm across all three salons. Exposures did not exceed the full-shift time-weighted average (TWA) ACGIH threshold limit value of 0.1 ppm for formaldehyde. At Salon B, we sampled seven employees for 2 days and three employees for 1 day each. At Salon C, we sampled three employees for 1 day each. At Salon D, we sampled four employees for 1 day each.

None of the personal air samples for ethyl acetate, n-butyl acetate, toluene, methyl methacrylate, or ethyl methacrylate were above any OELs. Personal air sampling results, summarized by salon, are presented in Table C3. Overall, we collected 22 full-shift samples for these chemicals. Ten employees participated in personal air sampling across 2 days at Salon B. We sampled three employees for one day at Salon C and four employees at Salon D for one day. Individual air sampling results, including minimum detectable concentrations (MDCs) and minimum quantifiable concentrations (MQCs), are in Section C: Tables C7 through C9.

Personal acetone concentrations were potentially several times higher among employees at Salon C than among employees at Salons B and D (Table C3). We measured substantial acetone breakthrough on the backup sorbent material for all three employees sampled in Salon C (> 10% breakthrough). The minimum estimated full-shift personal concentrations to acetone were 76 ppm, 84 ppm, and 88 ppm at Salon C. Given the breakthrough we observed, acetone air concentrations are likely to be higher than the minimum estimated concentrations we reported. At Salons B and D, full-shift personal concentrations to acetone ranged from 2.7 to 29 ppm. We did not statistically compare measurements across salons due to the small sample size in two of the three salons where we took personal measurements. See Section D for more information about OELs.

Area Air Concentrations of Particulates at Salons B–D

Summary results for the particulate area air samples are in Table C4. Mean total particulate concentrations were higher near the acrylic nail salon stations than simultaneous measurements taken at least 3 meters from the stations in Salons C and D. At all three salons (B–D), particulate concentrations spiked more frequently and to higher concentrations near the acrylic stations than farther from the acrylic stations.

Figure 4 shows a time history of particulate concentrations near acrylic nail stations and at a location at least 3 meters from acrylic nail stations at Salon C. The red box on Figure 4 shows a time period during which an employee was applying a dip acrylic nail manicure. This task was noted to be particularly dusty, as the powder used was very finely milled and easily aerosolized. Other spikes in particulate concentrations can be attributed to using the handheld rotary filing tool during acrylic nail shaping.

Volatile Organic Compounds in Bulk Nail Polish and Methyl and Ethyl Methacrylate Monomers in the Liquid Monomer Used to Create Acrylic Nails

Bulk nail polish concentrations for the chemicals we measured are presented in Table C5. Ethyl acetate, n-butyl acetate, and triphenyl phosphate concentrations were significantly lower in the used nail polish bulks than in the unused nail polish bulks as determined using Student's paired t-test ($P < 0.005$ for ethyl and n-butyl acetate; $P = 0.02$ for triphenyl phosphate). Concentrations of toluene and formaldehyde were not significantly different between the used and unused samples ($P = 0.17$ for toluene; $P = 0.23$ for formaldehyde).

Due to the difference in the limits of detection for dibutyl phthalate and the low number of detected values in the used polishes, we did not compare concentrations between the two sets of samples. The limit of detection for dibutyl phthalate was 100 microgram per milliliter (µg/mL) in the used bulk polishes, and it was only detected in two used samples. In the more recently purchased, unused polishes, the limit of detection was 2 µg/mL, and four samples contained detectable dibutyl phthalate.

At Salon C, the bulk methacrylate monomer liquid contained 190 µg/mL of methyl methacrylate and 800,000 µg/mL of ethyl methacrylate. Methyl methacrylate was listed as a "potentially hazardous ingredient" on the safety data sheet (SDS) provided by the salon for the acrylic monomer. Neither concentration nor ingredient percentages were listed on the SDS.

At Salon D, the bulk methacrylate monomer liquid contained 850,000 µg/mL of methyl methacrylate. Ethyl methacrylate was not found above the limit of detection (0.5 µg/mL). These results were consistent with the SDS provided by the salon. Methyl methacrylate was listed as an ingredient comprising at least 99.5% of the product.

Observations about Dermal Exposures and Glove Use

We specifically looked at dermal exposure to nail salon products and personal protective equipment (PPE) use in the course of providing nail services.

At Salons B–D, we observed 16 employees (nine at Salon B, three at Salon C, and four at Salon D) provide nail services during our visits. All employees who we observed providing acrylic nail services used brushes to apply acrylic during manicures at all of the salons, minimizing the potential for dermal exposure to acrylic.

We observed 10 of these 16 employees wearing gloves during nail services at least once (five at Salon B, one at Salon C, and four at Salon D). We did not observe glove use by the remaining six employees.

Employees wore gloves more commonly during pedicures than manicures. Of the 10 employees we observed giving pedicures, nine wore gloves at some point. Of the 14 employees we observed giving manicures, five wore gloves at some point. Some employees only wore gloves during nail polish removal or while shaping the acrylic nail using a powered rotary filing tool. We noted that five employees removed their gloves to apply nail polish during manicures and pedicures.

We observed eight employees providing both manicures and pedicures during their shift. Of these eight, one employee wore gloves during both services while four wore gloves at some point during the pedicure and not during the manicure. Two of the three remaining employees did not wear gloves during either service. One employee put on gloves to use acetone to remove gel polish.

We observed 10 employees either with polish on their own skin or using bare fingers to wipe away polish mistakes from around clients' nails.

At Salon B, of the five employees who wore gloves at least once, four wore nitrile gloves and one wore natural rubber latex gloves. One employee at Salon C sometimes wore nitrile gloves and at other times wore natural rubber latex gloves. At Salon D, all four employees wore natural rubber latex gloves. At Salon A, we did not observe glove use as systematically as we did at Salons B–D, but natural rubber latex gloves were available to employees. In general, we observed employees wearing gloves while providing pedicures, but not manicures.

During informal conversations at Salon B, employees noted that liquid callus remover caused irritation when it got on their skin. Many liquid callus softeners or removers, including the product at this salon, contain potassium hydroxide or other caustic ingredients. We examined the hands of eight employees from Salons C and D during our site visits. Two employees, both at Salon D, had dry, cracked skin on their thumbs on the day of the site visit.

We observed some employees wash their hands after providing nail services and before taking breaks, but at least one employee ate a meal before handwashing.

Confidential Medical Interviews

None of the 24 interviewed employees reported ever receiving a diagnosis of asthma, hay fever, or dermatitis. None of the employees reported any work-related respiratory, irritant, or skin symptoms within the 4 weeks prior to the interview.

Methods: Ventilation, Personal Protective Equipment, and Other Controls

We assessed ventilation, PPE, and other controls at the four salons through (1) observations about the ventilation system and air flow, (2) document review, and (3) confidential medical interviews.

We assessed the general ventilation at three salons—the fourth salon did not have any mechanical ventilation. We determined what type of ventilation system, if any, served the salon. We also reviewed all available SDSs for nail polishes, disinfectants, nail polish remover, and methacrylate monomer liquid and polymer products. During our confidential interviews with the 24 employees, we asked them about hazard communication, training, and PPE use.

Results: Ventilation, Personal Protective Equipment, and Other Controls

Ventilation

None of the shops had local exhaust ventilation (LEV) systems. One salon (Salon A) did not have a ducted ventilation system. Instead, Salon A had a recirculating air conditioning unit mounted on the salon wall. Two of the four salons (Salons B and C) had exhaust only ventilation, which exhausted indoor air to the outdoors. Make-up air (replacement air) was supplied through exterior windows and doors.

One salon (Salon D) had supply and return grilles, but we did not observe any airflow at the grilles using ventilation smoke. We could not ascertain if the ventilation system had been shut off in anticipation of the end of the business day or if the ventilation system was not operational for another purpose, such as to contain odors that had the potential to travel to other businesses. Additionally, Salon D had two small exhaust ducts (12 by 12 inches) located in or on the wall near the main shop ceiling, which were independent of the shop general ventilation. According to the mall maintenance staff, the exhaust system, but not the general ventilation system, was under the control of the shop owner, but it was not exhausting air at the time of our visit.

All salons had small desktop fans at nail stations At Salon B, the fan was incorporated into the desk light. At Salon C, they used a small tabletop air purifying unit, labeled as a "fume extractor."

Hazard Communication and Chemical Storage

As required by OSHA, all salon owners had obtained SDSs for the products that contain hazardous chemicals [OSHA 2012]. Some SDSs were outdated versions created before the introduction of the new OSHA Hazard Communication Standard in 2012.

Our interviews revealed that 14 (58%) of 24 interviewed employees reported knowing where to find the SDSs for chemicals used in the salon. Of these employees, 13 (93%) reported having read the SDSs. Four employees (17%) did not know what an SDS was. Regarding training on chemical hazards, 10 (42%) employees reported receiving training since beginning to work at the salon. Three employees at one salon declined to respond to this question.

At Salons A and B, bulk chemical containers, some not properly labeled, were stored underneath a sink (Figure 2). At Salon C, chemicals and nail products were stored in a room off the main salon floor (Figure 3). This unventilated room also served as an employee break area where employees ate meals. At Salon D, larger bottles of bulk chemicals were not stored on site, but at the home of the shop owner. The shop owner brought the larger bottles of chemicals in to refill the smaller bottles located at the technicians' stations. At Salon D, commonly used products like acetone and isopropyl alcohol were kept at technicians' stations in pressure-activated dispensing bottles (Figure B1). These dispensers were different from the containers at the stations in the other salons, which were typically squeeze dispensers with both open tip caps and twist open tip caps (Figure B2).

Figure B1. Pressure-activated product dispensers at Salon D. Employees press cotton balls or wipes on the top of the bottle to dispense product. Photo by NIOSH.

Figure B2. Bottles holding product at Salon C. The contents is squeezed out through a nozzle that either is twisted open or has a tip that remains open. Photo by NIOSH.

At Salons B and C, we observed bulk transfer of acetone from large containers to smaller containers. Employees poured used acetone from bowls into waste bottles. At Salon C, there was residual acetone in the used acetone bowls, which were stored on a shelf in the break room. We noted that acetone was also heated before being given to the client at Salon C, increasing evaporation. These activities can contribute to increased acetone concentrations in the air due to evaporation. Using ventilation smoke tubes, we observed that air from the break/storage room was pulled into the main salon area by the exhaust system. This pattern of air flow may have also contributed to acetone exposures when workers were on the shop floor.

Personal Protective Equipment Use

We observed employees at the four salons using surgical masks and N95 filtering facepiece respirators. Surgical masks are not considered respiratory protection and do not protect against particulate, gas, or vapor exposures in the air. Of the 16 employees we observed during visits to Salons B–D providing nail services, five wore N95 respirators, and five wore surgical masks. At Salon B, we observed one employee wearing a homemade cloth mask during parts of an acrylic nail manicure. This employee switched to an N95 filtering facepiece respirator before using a handheld rotary tool to shape the acrylic nail, which was the task that generated the most dust.

We observed that almost all employees who wore N95 filtering facepiece respirators wore them incorrectly. For example, some technicians wore their respirator using a single strap and some had straps incorrectly placed. Some people wore both straps under their ears. One employee wore the respirator sideways with the straps looping around the ears.

None of the salons had a written respiratory protection program. According to OSHA, employers are not required to have a written respiratory program when employees only voluntarily use N95 filtering facepiece respirators. These nail salons were located in a state that required them to stock N95 filtering facepiece respirators, but not the other components of a respiratory protection program.

Interview questions about surgical masks and respirators varied by visit. During our visit to Salon A and our first visit to Salon B, employees were asked if they wore a surgical mask at work: all 11 reported doing so. During our second visit to Salon B and visits to Salons C and D, we asked employees whether they used a surgical mask or respirator at work: 11 of 13 (85%) employees reported doing so. Table C6 shows the tasks associated with the use of respirators and surgical masks. In general, self-reported surgical mask or N95 respirator use during interviews was higher than observed use during our site visits.

Reported Glove Use

All interviewed employees reported wearing gloves when serving clients. However, as mentioned earlier, we observed that some employees removed gloves during some tasks, such as applying nail polish, applying acrylic nails, and removing nail polish from client's skin.

Discussion

Based on the interview and observation results, employees are at risk of developing musculoskeletal injuries, such as muscle strain and pain. Some employees reported neck, shoulder, and upper back pain. Previous studies comparing nail salon workers to office workers show that nail salon workers have a higher prevalence of musculoskeletal symptoms, including pain or discomfort in the shoulders and neck, and are at increased risk of developing musculoskeletal disorders [Gil Coury et al. 1999; Harris-Roberts et al. 2011; Park et al. 2014; Roelofs et al. 2008]. In this series of evaluations, we found that 4 of the 19 employees who had worked for at least 2 months had pain that they got better away from work.

Providing nail services required close inspection of the hands and feet of clients. Employees needed to do this work without straining their necks or backs to get a closer look. In general, we found that most employees did not have adjustable chairs and tables in the workplace. Employees with adjustable chairs and tables did not adjust them to improve their work positions.

Some chemicals in nail polish can be absorbed into the body through skin or cause skin conditions. For example, skin exposure to acrylic nail ingredients (methyl and ethyl methacrylates) can cause allergies and contact dermatitis or skin rash [ACGIH 2018a]. Wearing gloves can prevent dermal exposure to many chemicals. Employees reported using natural rubber latex and nitrile gloves while providing nail services, which was consistent with our observations. However, we frequently observed employees not wearing gloves during the entire service, which can lead to skin exposure. The employees we interviewed did not report skin irritation. However, during informal conversations, some employees stated that the callus remover used during pedicures caused skin irritation. White et al. [2013] surveyed 65 manicurists, of whom 80% reported "sometimes or rarely/never" using gloves during acrylic nail application and 8% reported "sometimes or rarely/never" using gloves during manicures and pedicures. Our observations are consistent with their findings based on self-report.

Providing nail services without gloves and removing nail polish with bare fingers contribute to dermal exposures to chemicals in nail polish, nail polish removers, and methacrylate (acrylic) nail particulate. One study found that nail salon technicians who did not wear gloves had higher dibutyl phthalate (a chemical in some nail polishes) metabolite levels in their urine at the end of their shifts compared with the beginning of their shifts. In contrast, nail salon technicians who wore gloves did not have higher metabolite levels in their urine samples at the end of their shifts compared with the beginning of their shifts [Kwapniewski et al. 2008]. In a study focused on occupational contributions to phthalate exposure, manicurists had about two-fold higher concentrations of a major dibutyl phthalate metabolite in their urine than the general population [Hines et al. 2008].

We observed frequent dermal exposure to nail polish among employees. The differences between the concentrations of chemicals measured in the used and new nail polishes might be attributed to two major influences: the age of the product collected in the field and changes in formulation between when the field product was purchased by the salon owners (unknown) and when we purchased the polishes (2016). As for the age of the product, volatile components evaporate over time, leading to lower concentrations of the volatile components and higher concentrations of less volatile components. As for reformulation, manufacturers of the polish may remove some components and replace them with others. For example, older polishes may contain dibutyl phthalate, a component manufacturers replaced with triphenyl phosphate in newer polishes [Nails Magazine 2011; Young et al. 2018].

If changing work practices or using tools cannot prevent dermal exposure to nail salon chemicals, certain types of gloves can protect against specific types of chemical exposures. For example, nitrile gloves protect against most chemicals used in nail salons, except acetone. Natural rubber latex gloves are effective at protecting against acetone exposure but can cause the development of allergies [Forsberg et al. 2014]. Vinyl or butyl gloves can be used as an alternative to natural rubber latex gloves for protection against unavoidable acetone exposure.

In addition to assessing dermal exposures, we measured several types of chemicals in the salon air. We found that none of the personal air sampling results for ethyl acetate, n-butyl acetate, toluene, methyl methacrylate, and ethyl methacrylate exceeded their respective OELs. Personal air sampling results for acetone in Salons B and D did not exceed OELs. We also compared the ethyl acetate and toluene concentrations we measured with those from an evaluation of several California nail salons [Quach et al. 2011]. Our measured concentrations of ethyl acetate (0.04–1.3 ppm) and toluene (not detected–0.16 ppm) were at the lower end of the ranges reported for these chemicals (0.02–5.5 ppm for ethyl acetate; 0.02–1.0 ppm for toluene).

Median acetone exposures were several times higher at Salon C than those at Salons B and D. Because the air sampling tubes contained acetone in the "backup" sorbent section, employees' exposures to acetone at Salon C were likely even higher than the concentrations we report. These relatively high acetone exposures may be due to the use of the unventilated break area that was also used to store bulk and waste acetone. The combination of several sources of acetone vapor, no ventilation in the break room, and the amount of time employees spent in the break room likely contributed to these employees' acetone exposures. We cannot determine whether employees' acetone exposures were above any OELs because precise concentrations cannot be determined.

Although none of the interviewed employees reported respiratory problems, exposure to methyl and ethyl methacrylates in the air can cause respiratory irritation and asthma. In one large study, salon workers were more likely to have asthma if they applied acrylic nails. The authors suggested that this may be related to exposure to methyl methacrylate [Kreiss et al. 2006]. Other investigators found that working as a nail technician for a longer period and with more hours using acrylic gel (which contains methacrylates) was associated with decreased lung function and airway inflammation [Reutman et al. 2009]. It is unknown what concentrations of methyl and ethyl methacrylates in air can lead to sensitization or asthma, but some individuals are more susceptible to developing these illnesses after exposure than others [ACGIH 2018a; Cosmetic Ingredient Review Expert Panel 2002].

Exposure to liquid methacrylate monomers on skin can cause irritation and dermatitis. The United States Food and Drug Administration removed products containing 100% methyl methacrylate monomer from the market because of health complaints about nail damage and deformity and contact dermatitis [FDA 2016; NIOSH 2010]. The sale, purchase, and use of methyl methacrylate monomer was banned in the state where the salons are located. However, one of the two monomer products we tested contained nearly 100% methyl methacrylate. We found that personal air exposures to methyl and ethyl methacrylates in this salon were well below OELs.

We measured formaldehyde at 0.005 to 0.020 ppm in personal air samples. Six of the personal air samples we collected were slightly higher than the NIOSH REL for formaldehyde of 0.016 ppm. The International Agency for Research on Cancer (IARC) classifies formaldehyde as a carcinogen (cancer-causing agent) [IARC 2012], and the NIOSH formaldehyde REL was developed on that basis.

It has become clear since the development of the NIOSH REL, which at the time was meant to be the "lowest feasible concentration," that the REL is commonly exceeded in indoor air.

In a representative study of 100 office buildings with no known indoor environmental quality problems, formaldehyde concentrations ranged from less than 0.003 to 0.042 ppm, with a 75th percentile concentration of 0.017 ppm [Environmental Protection Agency 2006]. These results indicate that at least 25 percent of the air samples collected in the office buildings studied had indoor formaldehyde concentrations above the NIOSH REL. Considering this, the formaldehyde levels measured in the nail salon were similar to those found in many other buildings within no known sources of formaldehyde. Introducing sufficient conditioned outdoor air, which would be expected to have a lower formaldehyde content than that measured in the personal air samples, may reduce formaldehyde concentrations indoors [Environmental Protection Agency 2011].

Some of the SDSs we reviewed in the salons were outdated. Updated SDSs typically can be found through manufacturers or product distributors. All of the SDSs we reviewed were written in English. Only 42% of the interviewed employees reported receiving training on the chemical hazards at their salon. As part of the OSHA Hazard Communication Standard, employers must make SDSs available to employees and train employees so that they understand the potential chemical hazards and how to use the products safely. Although not required by the OSHA Hazard Communication Standard, employees should also receive training conducted in a language that they understand.

Although personal air concentrations for the chemicals we sampled (other than formaldehyde) did not exceed their respective OELs, research suggests that nail salon work involving acrylic nails can contribute to worse respiratory health. To prevent work-related illness, it is advisable to reduce exposures to the extent possible with currently available engineering controls. LEV is used to remove contaminants near the point of generation to prevent occupational exposures. The salons we evaluated were not equipped with LEV.

LEV is not widely used in nail salons, but different LEV types have been evaluated by NIOSH and other occupational health researchers for their ability to reduce chemical and particulate exposures [Lee et al. 2000; NIOSH 2012; Spencer et al. 1997]. NIOSH tested the efficiency of a (1) downdraft nail table and a (2) side draft style LEV system in removing volatile compounds from the air at the table in an experimental setup [NIOSH 2012]. The downdraft nail salon table is built into the nail table and nail services are provided over the exhaust grate. The side draft LEV system is mobile, and the exhaust is placed next to the client's and employee's hands.

In the laboratory, the mean exposure reductions achieved by the LEV systems tested ranged from 51% to 62% across the 12 LEV configurations tested. NIOSH developed and tested both a single nail salon manicure table and a multistation system that were equipped with LEV [Lee et al. 2000; NIOSH 2012]. The ventilated multistation system designed by NIOSH engineers reduced short-term personal ethyl methacrylate exposures (not detected to 0.16 ppm across five stations) compared to exposures measured without LEV (1.8 to 11 ppm across four stations).

In a laboratory setting, the capacities of four commercially available, mobile, side-exhaust LEV systems to reduce acetone and acrylic particulate levels during nail services were assessed [Shakibaei 2014]. The LEV units filtered the exhaust and released it into the salon, rather than exhausting it outdoors.

Compared to concentrations at the workstation without LEV, introducing LEV to the nail station reduced acetone concentrations by 77% and particulate concentrations by 67% to 90% at the station [Shakibaei 2014].

Improving general exhaust ventilation can assist in reducing personal exposure by introducing outdoor air into the salon. With the American National Standards Institute (ANSI), ASHRAE developed a consensus standard for general ventilation in nail salons that calls for using a forced-air mechanical ventilation system that provides filtered supply air and exhausts indoor air to the outdoors [ANSI/ASHRAE 2016]. ANSI/ASHRAE recommends that the ventilation system provide a minimum of 20 cubic feet of outdoor air per person per minute in the salon, including employees and clients. Installing a ventilation system in the salon that meets the ANSI/ASHRAE recommendations would help dilute indoor concentrations of all volatile organic compounds, including formaldehyde.

In addition to providing sufficient dilution ventilation, good work practices can limit exposures to airborne chemicals in nail salons. For example, keeping lids on containers when not in use reduces evaporation of volatile chemicals into the air, which reduces odors as well. Additionally, using pressure-activated or spill preventing containers to store volatile chemicals, such as acetone-based nail polish remover, reduces evaporation. When removing acrylic nails or gel nail polish, nail salon technicians could moisten cotton with nail polish remover and wrap it around the client's nails with foil rather than placing the client's fingers in an open bowl of acetone nail polish remover.

While LEV is preferred to control personal exposures to particulate and vapors, NIOSH-approved N95 filtering facepiece respirators can be effective in protecting against particulate exposures when properly worn and fitted. However, they do not provide any protection against gas or vapor exposures like those we measured in the nail salons (e.g., formaldehyde, toluene, methacrylates, and acetone). If employees choose to wear respiratory protection against inhaling particulates like those produced during nail filing, they should wear N95 filtering facepiece respirators and be taught how to put them on properly. They should also receive OSHA Respiratory Protection Standard 1910.134 Appendix D, which the employer is required to provide to employees who wear N95 respirators voluntarily.

Limitations

We conducted all but one confidential medical interview with the assistance of an interpreter. Interpretation might have led to some missed communication between the interviewer and the employees. For example, interviewees did not report skin problems at Salon B, but during informal conversations, employees said that the callus remover had caused skin irritation. We do not know if the source of these inconsistencies is a reluctance to report health information or a misinterpretation of the interview questions based on language or cultural barriers. Additionally, the personal air exposure monitoring was conducted on 1 or 2 days and did not capture the variations that can occur with changes in (1) season or weather, (2) level of business activity, and (3) products used at each salon. We visited four salons, three of which participated in a full evaluation that included personal air monitoring. As such, the results may not be generalizable to all salons in the state.

Conclusions

In our evaluation of four nail salons, we found that employees worked in positions that pose risks for developing musculoskeletal disorders. Some employees reported musculoskeletal pain that improved away from work. None of the employees reported respiratory or skin symptoms; however, work practices and workplace conditions likely contributed to chemical exposures through the skin and lungs. Improving workplace equipment, ventilation, and chemical storage practices; providing training on ergonomic postures, chemical hazards, and health risks; and enhancing work practices and PPE use will help promote workplace health and safety of employees in the nail salons.

Section C: Tables

Summary and Other Tables

Table C1. Frequency of services provided by interviewed employees (n = 24)

Service	Number (%) of employees	Frequency, number (%)* of employees	
		Daily	Weekly
Standard polish manicure	21 (88)	19 (90)	2 (10)
Standard polish pedicure	21 (88)	18 (86)	3 (14)
Gel polish	17 (71)	13 (76)	4 (24)
Standard acrylic nails	15 (63)	14 (93)	1 (7)
Shellac polish	13 (54)	13 (100)	0
Waxing	9 (38)	5 (56)	4 (44)
Acrylic dip system†	7 (88)	4 (57)	3 (43)

*Percentage among employees who reported performing the service.
†Only employees at Salons C and D (n = 8) were asked about this service.

Table C2. Full-shift personal air concentrations of chemicals in air across Salons B–D, in ppm

Compound	Geometric mean	Concentration range	NIOSH REL	ACGIH TLV
Acetone* (n = 19)	9.06	2.7–29	250	250
Ethyl acetate (n = 22)	0.24	0.04–1.3	400	400
n-Butyl acetate (n = 22)	0.08	0.01–0.48	150	50
Toluene (n = 22)	0.01	ND–0.16	100	20
Formaldehyde (n = 24)	0.01	0.005–0.020	0.016	0.1
Ethyl methacrylate (n = 23)	0.15	ND–5.4	—	—
Methyl methacrylate (n = 23)	0.08	ND–1.5	100	50

ND = not detected

TLV = threshold limit value

*Three samples had acetone breakthrough into the backup sorbent material and were excluded from these calculations.

Table C3. Full-shift personal air concentrations of chemicals in air (in ppm) by salon

Compound	Salon B			Salon C			Salon D		
	GM	Range	No.*	GM	Range	No.	GM	Range	No.
Acetone	7.75	2.7–19	15	—	—†	3	13.6	8.9–29	4
Ethyl acetate	0.210	0.07–0.95	15	0.904	0.73–1.3	3	0.148	0.04–0.56	4
n-Butyl acetate	0.077	0.02–0.31	15	0.330	0.26–0.47	3	0.027	0.01–0.12	4
Toluene	0.003	ND–0.02	15	0.135	0.12–0.16	3	0.012	0.01–0.03	4
Formaldehyde	0.011	0.01–0.02	17	0.017	0.017–0.018	3	0.014	0.01–0.02	4
Methyl methacrylate	0.042	ND–1.4	16	1.30	1.1–1.4	3	0.315	0.12–1.5	4
Ethyl methacrylate	0.619	0.14–5.4	16	0.010	0.009–0.010	3	ND	ND	4

GM = Geometric mean

*At Salon B we sampled on 2 days. Ten employees participated across the 2 days. At the remaining salons, the number of samples was also the number of participants.

†Due to breakthrough into the backup sorbent material, the concentration cannot be calculated with confidence. The minimum estimated concentrations were 76 ppm, 84 ppm, and 88 ppm.

Table C4. Area particulate concentrations in air for Salons B–D, in milligrams per cubic meter (mg/m^3)

Salon	Within 0.5 meter of acrylic nail stations				3 meters or more from acrylic nail stations			
	Mean total	Maximum total	Mean respirable	Maximum respirable	Mean total	Maximum total	Mean respirable	Maximum respirable
Salon B*	0.024	1.4	0.011	0.70	0.082	1.31	0.051	1.0
Salon C	0.058	14	0.01	2.1	0.03	0.67	0.008	0.06
Salon D	0.030	0.71	0.007	0.24	0.018	0.52	0.007	0.37

*Measurements were taken on subsequent business days at Salon B, rather than simultaneously.

Table C5. Concentrations of selected chemicals in used and unused nail polish, in µg/mL

Compound	Used nail polish (n = 18)			Unused nail polish (n = 14)		
	Mean	Range	Detection limit	Mean	Range	Detection limit
Ethyl acetate	45,300	220–89,000	2	387,000	920–620,000	5
n-Butyl acetate	69,100	960–110,000	2	474,000	1,200–700,000	5
Toluene	9,780	ND–9,000†	2	159	5.7–410‡	5
Formaldehyde (%)	0.128	0.0010–1.2	0.0008	0.0474	0.0004–0.16†	0.0013
Dibutyl phthalate	—*	ND–14,000†	100	25	ND–160§	6
Triphenyl phosphate	812	0.6–3,500†	0.3	17,600	9.7–62,000	2

*Two of 18 values were above the detection limit.

†One measurement for this analyte was between the limit of detection and the limit of quantitation. The used nail polish limits of quantitation were 6.6 µg/mL for toluene, 330 µg/mL for dibutyl phthalate, and 0.86 µg/mL for triphenyl phosphate. The unused polish formaldehyde limit of quantitation was 0.0047%. For formaldehyde, the mean limit of detection is presented.

‡Two values were between the limit of detection and the limit of quantitation, which was 14 µg/mL for toluene in the unused nail polish.

§Three values were between the limit of detection and the limit of quantitation. The unused nail polish limit of quantitation was 17 µg/mL for dibutyl phthalate.

Table C6. Surgical mask and N95 respirator use by task among interviewed employees (n = 24)

Task	Number (%) of employees		
	Surgical mask*	N95 respirator	Surgical mask or N95 respirator
Standard acrylic nails	3 (13)	3 (13)	0 (0)
Standard manicure or pedicure	3 (13)	0 (0)	1 (4)
Serving customer	3 (13)	0 (0)	1 (4)
Filing nails	3 (13)	0 (0)	0 (0)
Gel polish	3 (13)	0 (0)	0 (0)
Handling chemicals	1 (4)	2 (8)	1 (4)
Acrylic dip system	0 (0)	1 (4)	0 (0)
All job tasks	7 (29)	0 (0)	0 (0)

*Eleven employees at two salons were only asked whether they wore a surgical mask at work. The remaining employees were asked whether they wore a surgical mask or respirator at work.

Individual Full-shift Personal Exposure Sampling Results

Table C7. Full-shift personal exposure measurements to acetone, ethyl acetate, n-butyl acetate, and toluene, in ppm

Salon	Participant	Sample time	Acetone*	Ethyl acetate	n-Butyl acetate	Toluene†
B	1	604	2.7	0.074	0.023	[0.002]
B	2	548	17	0.95	0.31	[0.002]
B	2	564	11	0.44	0.18	ND
B	3	570	19	0.63	0.31	0.024
B	3	540	6.5	0.17	0.10	0.021
B	4	533	10	0.57	0.23	0.009
B	5	588	6.7	0.27	0.10	[0.003]
B	5	519	5.6	0.12	0.041	[0.001]
B	6	372	5.9	0.082	0.033	[0.003]
B	6	389	9.5	0.069	0.028	ND
B	7	524	5.2	0.079	0.032	[0.003]
B	7	472	5.5	0.084	0.029	[0.001]
B	8	427	12	0.72	0.15	[0.003]
B	9	536	8.7	0.38	0.14	[0.001]
B	10	473	5.1	0.11	0.03	ND
C	1	604	—	0.73	0.26	0.12
C	2	575	—	1.3	0.47	0.16
C	3	553	—	0.80	0.29	0.13
D	1	574	8.9	0.041	0.010	0.009
D	2	508	10	0.21	0.018	0.009
D	3	397	13	0.10	0.026	0.010
D	4	321	29	0.56	0.12	0.027

[ ] = Estimated concentration: this concentration was between the minimum detectable and minimum quantifiable concentrations.

*Acetone exposures for employees at Salon C cannot accurately be calculated because of substantial breakthrough in the backup sample media. Minimum estimated concentrations were 76 ppm, 88 ppm, and 84 ppm for participants C1, C2, and C3, respectively.

†Toluene minimum detectable concentrations ranged from 0.001 to 0.002 ppm and minimum quantifiable concentrations ranged from 0.003 to 0.006 ppm.

Table C8. Full-shift personal exposures measurements to ethyl methacrylate and methyl methacrylate, in ppm

Salon	Participant	Sample time	Ethyl methacrylate*	Methyl methacrylate†
B	1	631	0.55	0.026
B	1	581	0.99	0.029
B	2	547	0.25	0.033
B	2	563	0.22	0.009
B	3	569	0.24	0.021
B	3	541	0.20	0.011
B	4	536	0.14	0.024
B	4	525	0.22	ND
B	5	590	5.4	0.37
B	5	520	5.2	0.32
B	6	534	1.5	0.085
B	6	206	0.30	[0.015]
B	7	526	1.8	0.14
B	7	471	1.7	0.067
B	8	426	0.25	0.027
B	10	474	1.1	0.047
C	1	603	[0.009]	1.4
C	2	574	[0.010]	1.4
C	3	553	[0.010]	1.1
D	1	575	ND	1.5
D	2	215	ND	0.12
D	3	282	ND	0.18
D	4	319	ND	0.33

[ ] = Estimated concentration: this concentration was between the minimum detectable and minimum quantifiable concentrations.

*Ethyl methacrylate minimum detectable concentrations ranged from 0.001 to 0.01 ppm and minimum quantifiable concentrations ranged from 0.005 to 0.03 ppm.

†Methyl methacrylate minimum detectable concentrations ranged from 0.002 to 0.01 ppm and minimum quantifiable concentrations ranged from 0.006 to 0.04 ppm.

Table C9. Full-shift personal exposures measurements to formaldehyde, in ppm

Salon	Participant	Sample time	Formaldehyde*
B	1	583	0.015
B	1	503	0.009
B	2	544	0.013
B	2	560	0.008
B	3	566	0.013
B	3	533	0.007
B	4	530	0.014
B	4	522	[0.005]
B	5	583	0.020
B	5	517	0.012
B	6	530	0.013
B	6	550	0.006
B	7	521	0.020
B	7	469	0.012
B	8	423	0.011
B	9	532	0.012
B	10	472	0.008
C	1	599	0.018
C	2	569	0.017
C	3	552	0.018
D	1	570	0.012
D	2	507	0.012
D	3	327	0.013
D	4	319	0.018

[ ] = Estimated concentration: this concentration was between the minimum detectable and minimum quantifiable concentrations.

*Formaldehyde minimum quantifiable concentrations ranged from 0.003 to 0.007 ppm.

Section D: Occupational Exposure Limits

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 short-term exposure limits ceiling values. Unless otherwise noted, the short-term exposure limit 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 permissible exposure limits (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, PPE, 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 2018b].

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.

Formaldehyde

Formaldehyde is found in nail polish and nail hardener. Formaldehyde is a potential dermal sensitizer and respiratory sensitizer [ACGIH 2018a]. NIOSH recognized formaldehyde as a potential occupational carcinogen in 1981. The guidance, following the NIOSH carcinogen policy in existence at the time, was to reduce formaldehyde exposure to the "lowest feasible limit," defined as the analytical limit of quantification at the time of 0.016 ppm for up to 8 hours [Lemen 1987; NIOSH 1981, 1995].

Additional research has shown that sometimes ambient air can have formaldehyde levels as high as or higher than the NIOSH REL, even with no obvious source nearby [Environmental Protection Agency 2006, 2011]. Therefore, NIOSH recommends that employers and employees minimize formaldehyde exposures as much as possible. This can be done by removing known sources of formaldehyde and improving building ventilation by introducing sufficient outdoor air. The most commonly reported and best documented health complaints due to exposure to low concentrations of formaldehyde include nasal congestion, headaches, skin rash, asthma, and irritation of the eyes, nose, and throat. The ACGIH TLV for formaldehyde is 0.1 ppm as a full-shift TWA and 0.3 ppm as a ceiling limit. The OSHA PEL is 0.75 ppm as a TWA and 2 ppm as a short-term exposure limit.

Methyl Methacrylate and Ethyl Methacrylate

Methacrylates are acrylic monomers that react to form polymers in the production of acrylic products; printing inks, coatings, and adhesives; and dental and medical restorative materials. Methyl methacrylate and ethyl methacrylate are used to form artificial nails by mixing methacrylate monomer liquid with methacrylate polymer powder. In the monomer form, methacrylates are skin sensitizers (skin contact can lead to an allergic response) and irritants of the skin, eyes, and respiratory tract [Borak et al. 2011; Sauni et al. 2008]. Methyl methacrylate has also been associated with allergic contact dermatitis, loss of smell, and neurological symptoms [Sauni et al. 2008].

In one large study, salon workers were more likely to have asthma if they applied acrylic nails; the authors suggested this might be related to methacrylates [Kreiss et al. 2006]. The U.S. Food and Drug Administration has removed products containing 100% methyl methacrylate monomer from the market because it is linked to contact dermatitis and nail damage and deformity. The NIOSH REL and OSHA

PEL for methyl methacrylate are 100 ppm as a TWA. The ACGIH TLV for methyl methacrylate is 50 ppm. There is no NIOSH REL, OSHA PEL, or ACGIH TLV for ethyl methacrylate.

Ethyl Acetate and n-Butyl Acetate

Ethyl acetate and n-butyl acetate are solvents. They are used in glues, varnishes, lacquers, nail polish removers, and artificial fruit flavors. n-Butyl acetate is comprised of several isomers that are often discussed together as a single class. NIOSH, OSHA, and ACGIH established OELs for butyl acetates as a class.

The NIOSH REL, OSHA PEL, and ACGIH TLV for ethyl acetate are 400 ppm. The TLV was established to prevent irritation of the eyes, nose, and upper airways [ACGIH 2018a]. Ethyl acetate is relatively low in toxicity and a fruity odor can be detectable at around 3.9 ppm.

The NIOSH REL and OSHA PEL for n-butyl acetate are 150 ppm. The ACGIH TLV is 50 ppm for n-butyl acetate and was set to prevent the risk of eye and nasal irritation that some isomers can cause. At levels that are several times above the TLV, other effects like hyperactivity and liver changes can occur.

Toluene

Toluene is a solvent that is used in a variety of industries and products. In particular, it is added to some nail salon products, such as nail polish. Toluene easily evaporates into the air at normal indoor and outdoor temperatures. Exposure to toluene can cause adverse central nervous system effects. Toluene exposure can also cause reproductive problems, like spontaneous abortion or fetal malformation [Environmental Protection Agency 2005]. ACGIH recommends that workplace toluene exposure be kept below 20 ppm to protect against subclinical effects, like changes in color perception, and to protect against spontaneous abortion in pregnant employees [ACGIH 2018a]. The NIOSH REL for toluene is 100 ppm [NIOSH 2010].

Acetone

Acetone is found in many nail polish removers. Overexposure to acetone in the air can irritate the upper respiratory tract and eyes and cause gastrointestinal and central nervous system health effects. Workers who are regularly exposed to acetone are less likely to experience irritation effects than workers without repeated exposures [Agency for Toxic Substances and Disease Registry 2011; Dalton et al. 1997]. Human carcinogenicity for acetone has not been classified by ACGIH, IARC, or the National Toxicology Program. Significant acetone exposure (> 500 ppm) can upregulate metabolic enzymes that can increase the cancer-causing potential of other chemicals like chloroform and benzene [ACGIH 2018a]. The NIOSH REL and the ACGIH TLV for acetone are 250 ppm, and the OSHA PEL is 1,000 ppm.

Section E: References

Health and Nail Salons

Gil Coury HJC, Mattar FL, Fernandes LS, Oishi J [1999]. Upper limb symptoms and occupational aspects in manicurists. Int J Ind Ergon *23*(3):139–147, https://doi.org/10.1016/S0169-8141(97)00034-6.

Harris-Roberts J, Bowen J, Sumner J, Stocks-Greaves M, Bradshaw L, Fishwick D, Barber CM [2011]. Work-related symptoms in nail salon technicians. Occup Med *61*(5):335–340, http://dx.doi.org/10.1093/occmed/kqr096.

Kreiss K, Esfahani RS, Antao VC, Odencrantz J, Lezotte DC, Hoffman RE [2006]. Risk factors for asthma among cosmetology professionals in Colorado. J Occup Environ Med *48*(10):1062–1069, http://dx.doi.org/10.1097/01.jom.0000237348.32645.eb.

OSHA [2012]. Stay healthy and safe while giving manicures and pedicures: a guide for nail salon workers. Washington, DC: U.S. Department of Labor, Occupational Safety and Health Administration, https://www.osha.gov/Publications/3542nail-salon-workers-guide.pdf.

Reutman SR, Rohs AM, Clark JC, Johnson BC, Sammons DL, Toennis CA, Robertson SA, MacKenzie BA, Lockey JE [2009]. A pilot respiratory health assessment of nail technicians: symptoms, lung function, and airway inflammation. Am J Ind Med *52*(11):868–875, http://dx.doi.org/10.1002/ajim.20751.

Roelofs C, Azaroff LS, Holcroft C, Nguyen H, Doan T [2008]. Results from a community-based occupational health survey of Vietnamese-American nail salon workers. J Immigr Minor Health *10*(4):353–361, http://dx.doi.org/10.1007/s10903-007-9084-4.

Sauni R, Kauppi P, Alanko K, Henriks-Eckerman M-L, Tuppurainen M, Hannu T [2008]. Occupational asthma caused by sculptured nails containing methacrylates. Am J Ind Med *51*(12):968–974, http://dx.doi.org/doi:10.1002/ajim.20633.

White H, Khan K, Lau C, Leung H, Montgomery D, Rohlman DS [2015]. Identifying health and safety concerns in Southeast Asian immigrant nail salon workers. Arch Environ Occup Health *70*(4):196–203, http://dx.doi.org/10.1080/19338244.2013.853644.

Exposures and Processes in Nail Salons

Borak J, Fields C, Andrews LS, Pemberton MA [2011]. Methyl methacrylate and respiratory sensitization: a critical review. Crit Rev Toxicol *41*(3):230–268, http://dx.doi.org/10.3109/10408444.2010.532768.

Cosmetic Ingredient Review Expert Panel [2002]. Amended final report on the safety assessment of ethyl methacrylate. Int J Toxicol *21*(Suppl 1):63–79, http://dx.doi.org/10.1080/10915810290096397.

FDA [2016]. Cosmetics: nail care products. Washington, DC: U.S. Food and Drug Administration, https://www.fda.gov/cosmetics/productsingredients/products/ucm127068.

Hines CJ, Nilsen Hopf NB, Deddens JA, Calafat AM, Silva MJ, Grote AA, Sammons DL [2008]. Urinary phthalate metabolite concentrations among workers in selected industries: a pilot biomonitoring study. Ann Occup Hyg *53*(1):1–17, http://dx.doi.org/10.1093/annhyg/men066.

Kwapniewski R, Kozaczka S, Hauser R, Silva MJ, Calafat AM, Duty SM [2008]. Occupational exposure to dibutyl phthalate among manicurists. J Occup Environ Med *50*(6):705–711, http://dx.doi.org/10.1097/JOM.0b013e3181651571.

Nails Magazine [2011]. Secret ingredient: nail polish, May 19, http://www.nailsmag.com/article/92314/secret-ingredient-nail-polish.

Park S, Gwak S, Choi S [2014]. Assessment of occupational symptoms and chemical exposures for nail salon technicians in Daegu City, Korea. J Prev Med Public Health *47*(3):169–176, http://dx.doi.org/10.3961/jpmph.2014.47.3.169.

Quach T, Gunier R, Tran A, Von Behren J, Doan-Billings P, Nguyen K, Okahara L, Lui BY, Nguyen M, Huynh J, Reynolds P [2011]. Characterizing workplace exposures in Vietnamese women working in California nail salons. Am J Public Health *101*(Suppl 1):S271–S276, http://dx.doi.org/10.2105/AJPH.2010.300099.

Young AS, Allen JG, Kim U, Seller S, Webster TF, Kannan K, Ceballos DM [2018]. Phthalate and organophosphate plasticizers in nail polish: evaluation of labels and ingredients. Environ Sci Technol *52*(21):12841–12850, http://dx.doi.org/10.1021/acs.est.8b04495.

Methods

Hornung RW, Reed LD [1990]. Estimation of average concentration in the presence of nondetectable values. J Appl Occup Environ Hyg *5*(1):46–51, https://doi.org/10.1080/1047322X.1990.10389587.

NIOSH [2019]. NIOSH manual of analytical methods (NMAM). 5th ed. By O'Connor PF, Ashley K, eds. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2014-151, http://www.cdc.gov/niosh/nmam.

OSHA [2005]. Formaldehyde (diffusive samplers). Washington, DC: U.S. Department of Labor, Occupational Safety and Health Administration, https://www.osha.gov/dts/sltc/methods/mdt/mdt1007/1007.pdf.

Occupational Exposure Limits and Consensus Standards

ACGIH [2018a]. Documentation of the threshold limit values and biological exposure indices. 7th ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

ACGIH [2018b]. 2018 TLVs® and BEIs®: threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

Agency for Toxic Substances and Disease Registry [2011]. Addendum to the toxicological profile for acetone. Atlanta, GA: U.S. Department of Human Services, Centers for Disease Control and Prevention, Agency for Toxic Substances and Disease Registry, https://www.atsdr.cdc.gov/toxprofiles/acetone_addendum.pdf.

ANSI/ASHRAE [2016]. Standard 62.1-2016. Ventilation for acceptable indoor air quality. American National Standards Institute. Atlanta, GA: ASHRAE.

CFR. Code of Federal Regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

Dalton P, Wysocki CJ, Brody MJ, Lawley HJ [1997]. Perceived odor, irritation, and health symptoms following short-term exposure to acetone. Am J Ind Med *31*(5):558-69, https://doi.org/10.1002/(SICI)1097-0274(199705)31:5<558::AID-AJIM10>3.0.CO;2-Y.

Environmental Protection Agency [2005]. Toxicological review of toluene. Washington, DC: U.S. Environmental Protection Agency, EPA Publication No. 365-R-05-004, https://www.epa.gov/sites/production/files/2014-03/documents/toluene_toxicology_review_0118tr_3v.pdf.

Environmental Protection Agency [2006]. Building assessment survey and evaluation (BASE) study; data on indoor air quality in public and commercial buildings. Washington, DC: U.S. Environmental Protection Agency, Office of Air and Radiation, Office of Atmospheric and Indoor Air Programs, Indoor Air Division, EPA Publication No. 402-C-06-002, https://www.epa.gov/indoor-air-quality-iaq/building-assessment-survey-and-evaluation-study.

Environmental Protection Agency [2011]. 2011 National air toxics assessment. Washington, DC: U.S. Environmental Protection Agency, https://www.epa.gov/national-air-toxics-assessment/2011-national-air-toxics-assessment.

IARC [2012]. IARC monographs on the evaluation of carcinogenic risks to humans. A review of human carcinogens: formaldehyde. Vol. 100F. Lyon, France: World Health Organization, International Agency for Research on Cancer.

Lemen RA [1987]. Official letter from R.A. Lemen, Division of Standards Development and Technology Transfer, National Institute for Occupational Safety and Health, U.S. Department of Health and Human Services, to Tom Hall, Docket Office, U.S. Department of Labor, Washington, DC, February 9.

NIOSH [1981]. Formaldehyde: evidence of carcinogenicity. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control, National Institute for Occupational Safety and Health. DHHS (NIOSH) Publication No. 81-111, https://www.cdc.gov/niosh/docs/81-111/.

NIOSH [1995]. NIOSH recommended exposure limit policy. In: NIOSH policy statements, September 1995. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health.

NIOSH [2010]. NIOSH pocket guide to chemical hazards. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2010-168c, http://www.cdc.gov/niosh/npg/.

Personal Protective Equipment

Forsberg K, Van den Borre A, Henry N III, Zeigler JP [2014]. Quick selection guide to chemical protective clothing. 6th ed. New York: Van Nostrand.

Ventilation in Nail Salons

Lee S, McCammon J, McGlothin C, Phillips J [2000]. A new manicure table for applying artificial fingernails. Appl Occup Environ Hyg *15*(1):1–4, http://dx.doi.org/10.1080/104732200301755.

NIOSH [2012]. An evaluation of local exhaust ventilation systems for controlling hazardous exposures in nail salons. By Marlow DA, Looney T, Reutman S. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, EPHB Report No. 005-164, https://www.cdc.gov/niosh/surveyreports/pdfs/005-164.pdf.

Shakibaei N [2014]. Reducing workers' exposures to chemicals and dust in nail salons using local exhaust ventilation systems. Thesis. Seattle, WA: University of Washington, https://digital.lib.washington.edu/researchworks/handle/1773/26348.

Spencer AB, Estill CF, McCammon JB, Mickelsen RL, Johnston OE [1997]. Control of ethyl methacrylate exposures during the application of artificial fingernails. Am Ind Hyg Assoc J *58*(3):214–218, http://dx.doi.org/10.1080/15428119791012865.

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