HealthHazard® Evaluation Program

Evaluation of Occupational Exposures to Illicit Drugs at Forensic Sciences Laboratories

HHE Report No. 2018-0116-3370

March 2020

Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

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

David A. Jackson, MD

Jessica F. Li, MSPH

Analytical Support: Roy Gerona and Andrew Reckers, University of California, San Francisco; Deborah Sammons (NIOSH); Bureau Veritas North America

Desktop Publisher: Shawna Watts

Editor: Cheryl Hamilton

Industrial Hygiene Field Assistance: Michael Grant, Karl Feldmann, Michael Zhou

Logistics: Donnie Booher, Kevin Moore

Medical Field Assistance: Sophia Chiu, Deborah Sammons

Keywords: North American Industry Classification System (NAICS) 922120 (Police Protection), Michigan, Forensic Laboratory, Forensic Scientist, Forensic Chemist, Law Enforcement, Illicit Drug, Cocaine, Opioid, Heroin, Fentanyl, Methamphetamine

Disclaimer

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

Availability of Report

Recommended Citation

NIOSH [2020]. Evaluation of occupational exposures to illicit drugs at forensic sciences laboratories. By Broadwater KR, Jackson DA, Li JF. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Health Hazard Evaluation Report 2018-0116-3370, https://www.cdc.gov/niosh/hhe/reports/pdfs/2018-0116-3370.pdf.

Table of Contents

Main Report

Supporting Technical Information

This page left intentionally blank

Introduction

Request

Management at a state police forensic sciences division was concerned about potential occupational exposure to illicit drugs among employees working in their controlled substances laboratories.

Workplace

The police forensic sciences division operated eight controlled substances laboratories. Each facility served a specific geographic region of the state. Employees of the facilities performed forensic analysis on a wide variety of evidence collected by a variety of submitting law enforcement agencies. This request focused on occupational exposures to illicit drugs—no work-related health effects were noted in the request. We focused our evaluation on employees who routinely handled and/or analyzed suspected illicit drug evidence in controlled substances laboratories. Specifically, we included forensic scientists, forensic technicians, and laboratory managers who supervised controlled substances laboratory employees. As a group, we refer to all these job classifications as employees or chemists.

At the time of our first visit, 42 forensic scientists, forensic technicians, and laboratory managers worked across the eight laboratories.

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

Our Approach

We visited seven of the eight laboratory facilities at least once and four of these laboratories a second time to learn more about work-related health concerns and to measure work-related exposures among employees in the controlled substances units (CSUs). Our first visit was in March 2018, and our return visits were in January, February, and March 2019. During our site visits, we completed the following activities:

- Observed work processes, work practices, and workplace conditions.
- Measured 18 forensic laboratory chemists' exposures to cocaine, fentanyl, heroin, and methamphetamine in air, on hands, and on surfaces in the CSU laboratories and office areas.
- Assessed the ventilation chemical hoods and the airflow among laboratory areas, hallways, and administrative areas.
- Held confidential medical interviews with 31 employees at seven laboratories and administered medical questionnaires with 19 employees at four laboratories.
- Tested 18 chemists' urine for cocaine, fentanyl, heroin, methamphetamine, and several metabolites (breakdown products) of these drugs.

We also reviewed these relevant records:

- Safety and health program manuals, dated 10/31/2017.
- Laboratory standard operating procedures, dated 1/9/2018.
- Respiratory Protection Program, undated.
- Laboratory surface sampling results from sampling completed prior to our visits, dated 7/3/2018.

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

Our Key Findings

Cocaine, fentanyl, heroin, and methamphetamine were found in the air, on surfaces, and on employee hands. Cocaine, fentanyl (and their metabolites), and methamphetamine were found in employee urine.

- None of the tested employees reported any work-related health effects felt to be related to handling the illicit drugs.
- Fourteen employees had cocaine, fentanyl, and/or methamphetamine (or one of their metabolites) in their urine, but none of the urine concentrations of the target drugs or metabolites met or exceeded available federal workplace drug testing cutoffs.
- Forensic laboratory employees working inside the CSU on the sampling day had cocaine (15 of 17), fentanyl (2 of 17), heroin (8 of 17), and methamphetamine (15 of 17) in their personal air samples. One person working outside the CSU in evidence receiving did not have any of these drugs in their personal air sample.
- None of the fentanyl concentrations in air were higher than the occupational exposure limit set by a pharmaceutical company that manufactures fentanyl. The other controlled substances do not have occupational exposure limits. There are no occupational exposure limits set by the federal government or consensus organizations for any of the four drugs sampled.
- Four of the sampled drugs were found in the personal air samples of some employees who had not worked with those drugs that day.
- Cocaine (18 of 18), fentanyl (13 of 18), heroin (17 of 18), and methamphetamine (18 of 18) were found on most employees' hands before leaving the laboratory at the end of the day. When these drugs were found on employees' hands, the end-of-day samples had higher amounts than samples taken at the beginning of the day.

- Some employees who had positive handwipe samples for cocaine, methamphetamine, heroin, and fentanyl had not worked with evidence containing those drugs on the day we did handwipe sampling.
- Laboratory benchtop surface wipe samples had cocaine (27 of 27), fentanyl (26 of 27), heroin (25 of 27), and methamphetamine (26 of 27).
- California law states that property contaminated by fentanyl laboratory activity is safe for human occupancy if the level of fentanyl is below the "detection level." As mentioned above, we found fentanyl in 26 of our 27 samples. Additionally, one chemical hood bench sample, three keyboard samples, and four laboratory bench samples exceeded another proposed fentanyl-contamination remediation limit. No surfaces exceeded a workplace surface limit developed by a pharmaceutical fentanyl manufacturer.
- Six surfaces, all in the CSU laboratories, exceeded the most common state limit on methamphetamine contamination in remediated spaces.

Work practices and conditions may have contributed to unintentional employee exposures to cocaine, fentanyl, heroin, and methamphetamine

- Employees utilized a variety of cleaning practices using materials including methanol, various hydrogen peroxide solutions, disinfecting wipes, and water. Sometimes these practices were not consistent with the safety manual procedures regarding cleaning laboratory surfaces.
- Bulk chemicals and waste were stored in some chemical hoods in a way that could obstruct airflow. We measured areas of low or no face velocity at one chemical hood.
- Ten of the sixteen chemical hoods we assessed in the laboratory areas did not have average face velocities that met American National Standards Institute (ANSI) and American Industrial Hygiene Association (AIHA) guidelines.
- Per their training and longtime laboratory practice, employees took net weights of unknown powders. Employees used both open and enclosed scales in the laboratories. Sometimes they had to carry the evidence on weigh paper or in weigh boats across the room to a common use scale.
- Employees reported dry sweeping and dry wiping during laboratory cleaning. We observed an employee dry brush a small spill off a balance during our visit. Dry sweeping equipment was available at several laboratories: handheld brushes, brooms, and dustpans.
- We observed personal protective equipment use and storage procedures that were (1) not appropriate with good safety and health practices, and (2) inconsistent with laboratory safety manual requirements.
- Employees reported sometimes eating or drinking in controlled substances laboratories (21%) and never or sometimes washing hands before eating/drinking/smoking (21%) or leaving the laboratory (58%).

- Forensic scientists at one laboratory were sometimes startled while handling unknown suspected drugs by routine, but unannounced, firearm discharges into a water tank in an adjacent room.

Employees reported several past incidents of skin, breathing, or mucus membrane exposure to controlled substances at work

- No symptoms were reported with any of these incidents.
- None of the incidents were reported to managers at the time they occurred.

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	↑ Enhanced image and reputation
↑ Better workplace morale	↑ Superior products, processes, and services
↑ Easier employee recruiting and retention	↑ May 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 practical, administrative measures and personal protective equipment might be needed. Read more about the hierarchy of controls at 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*" at https://www.osha.gov/shpguidelines/index.html.

Recommendation 1: Reduce employees' exposures to cocaine, fentanyl, heroin, and methamphetamine

Why? We have no indication that the current work exposures to cocaine, fentanyl, heroin, and methamphetamine that we detected have impacted employees' health. However, following sound occupational health practice, we recommend minimizing workplace exposures to controlled substances.

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

Improve the performance of existing ventilated workspaces. Increase the availability and use of enclosed or semi-enclosed ventilated spaces.

- Consult with a ventilation engineer when building new facilities or renovating existing facilities about adding enclosed or semi-enclosed ventilated workstations that are designed for handling powders with biologically active ingredients. Use consensus standards published by ANSI/AIHA and ASHRAE when designing new laboratory spaces.
- Provide locally ventilated workspace in controlled substances laboratories where forensic laboratory scientists can handle evidence (e.g., in portable powder hoods or existing chemical hoods) until enclosed or semi-enclosed ventilated spaces can be installed to reduce reliance on respirators.
- Remove bulk chemicals and bulk waste from chemical hoods. If materials need to be stored in the chemical hood, elevate materials in the hood at least 2 inches from the benchtop in the hood to accommodate airflow.
- Ensure existing chemical hoods conform to consensus standards regarding hood performance in laboratories. If the average face velocity is not within 80–120 feet per minute or if there are areas of low or no airflow at the hood face, the hood fan may need to be serviced or the contents of the chemical hood may need to be reorganized, placed on a stand, or removed. More information about chemical hood performance and maintenance can be found in ASHRAE Standard 110 and ANSI/AIHA Z9.5.
- Encourage employees to consistently follow the policy for when to use chemical hoods or other ventilated enclosures during controlled substance sampling and analysis.
- Test and balance the laboratory building ventilation systems to ensure laboratory spaces are negatively pressurized relative to exterior areas, such as hallways, offices, and instrument rooms.

Update laboratory protocols to reduce employees’ exposure to controlled substances during handling and analysis.

- Eliminate the requirement to take net weights of evidence whenever it is not strictly needed for law enforcement purposes or legal proceedings. This will reduce the risk of controlled substances becoming airborne during transfer from packaging to scales.
- Eliminate the need to use enclosed analytical balances for weighing powders where possible. This will reduce the risk of spills from weigh paper or boats catching on the sides of the balance enclosure during transfer of controlled substances onto these balances.

Encourage adherence to existing cleaning and hygiene protocols to keep laboratory and office surfaces as free as practicable of contaminants.

- Encourage employees to follow the cleaning protocols established in the health and safety manual. Update procedures as necessary when new information or guidance is published on the topic of forensic laboratory surface cleaning protocols.
- Standardize cleaning products across the CSUs and provide hands-on training demonstrating approved cleaning products and methods. Instruct employees to avoid using cleaning products (such as biological disinfectant wipes) not designed or approved to clean benchtops.
- Provide, at a minimum, annual training to ensure compliance with approved cleaning practices.
- Use wet cleaning methods or a vacuum equipped with a high efficiency particulate air filter for cleaning contaminated laboratory surfaces.
- Do not dry sweep or use dry brushing or wiping when cleaning laboratory surfaces, including balances.
- Purchase nonporous, wipeable chairs for laboratories as they need to be replaced.

Train employees on laboratory handwashing policies.

- Require employees to wash their hands immediately after handling evidence and chemicals and before leaving the laboratory spaces. Remind them to always wash their hands before eating, drinking, smoking, applying cosmetics, or using the bathroom.
- Ensure all laboratories have handwashing stations stocked with soap and single use paper towels as close to the laboratory exit as practicable.
- When designing new laboratories or renovating existing laboratories, include in the design handwashing antechambers that are separated from the controlled substances laboratory to limit cross-contamination of the handwashing area. The sinks should be touchless: either foot or sensor activated.

Improve adherence to policies on respirator use, maintenance, and replacement that are specific to CSU laboratory work.

- Retrain employees on N95 filtering facepiece respirator disposal and replacement policies and monitor compliance with existing policy. Require employees to discard and replace contaminated N95 respirators. Instruct employees to refrain from storing used N95 respirators and to keep unused respirators in the original container until use.
- Train employees on (1) the proper way to put on (donning) and take off (doffing) their respirators and (2) how to clean and store their half-mask elastomeric air purifying respirators. If air purifying respirators are stored with cartridges, they must be in a sealed bag.
- Establish and communicate a schedule for replacing half-mask elastomeric air purifying respirators cartridges for CSU employees. The schedule can be based on time in use or shifts in use, assuming the respirators are stored correctly between uses.
- Find additional resources on respiratory protection and training at this website: https://www.cdc.gov/niosh/topics/respirators/default.html.

Establish laboratory coat laundry schedules and storage policies.

- Develop, in partnership with individual laboratory management and employees, an explicit, written laundering schedule for laboratory coats.
- Tell employees that their used laboratory coats should be stored in the laboratory, near the exit, and should not be stored in office areas, break areas, or hallways. Encourage use of coat racks and/or hangers for laboratory coat storage when employees are not in the laboratory. Install laboratory coat storage if it is not already available.
- Advise employees to refrain from hanging used laboratory coats on the backs of their laboratory bench chairs or other laboratory equipment.

Evaluate the use and acceptability of new personal protective equipment periodically after introduction.

- Address concerns of employees who have issues with their prescription safety glasses where possible.
- Provide employees who use prescription eyeglasses with side shields if they decline prescription safety glasses.
- Solicit feedback on the use of newly provided respirators.

Train staff on effective glove use to protect against skin exposure and transfer of contamination from inside the laboratory to outside

- Train staff on how to don and doff gloves in a manner than prevents self-contamination. Tell them to always wear gloves when handling evidence that has been taken out of the law enforcement packaging, even if the material is still contained within the primary packaging in which it was seized.
- Encourage staff to discard gloves immediately after doffing gloves.
- Discard all remaining latex gloves. Natural rubber latex can cause sensitization and result in local and systemic allergic reaction, and its use should be avoided. Update the health and safety manual to remove references to latex glove availability and use.
    - 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/.

Establish a policy requiring chemists to be notified just before the discharge of firearms into the water tank, where applicable.

- Notification of firearms discharging would allow the chemists to act to reduce the risk of spills.

Recommendation 2: Improve communication between employees and laboratory management regarding health and safety policies and practices

Why? Ongoing communication regarding health and safety policies and upcoming changes increases employee engagement on the topic. Explicit safety and health commitment from laboratory and unit management may increase employee compliance with health and safety policies.

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

Include representatives from all CSUs on the health and safety committee and solicit their feedback on health and safety policy development and implementation.

- Include representatives from all CSUs to help employees feel that they are being heard and ensure that their specific issues can be discussed to increase acceptability of and adherence to safety and health policies.
- Ask CSU laboratory managers to communicate with their employees about leaderships' commitment to employee health and safety and the important role each employee has in health and safety policy implementation in the laboratories.

Continue periodic training involving all health and safety policies and programs, including the updated naloxone program.

Provide opportunities for employees to submit anonymous feedback or concerns regarding laboratory health and safety.

- Allowing for anonymous feedback may lead to employees being more likely to report concerns.

Have supervisors recognize employees who are performing tasks safely.

Encourage employees to report possible exposures to and health effects resulting from exposure to illicit drugs to their supervisors.

- Employees with new or ongoing health concerns should be encouraged to talk with their healthcare providers about potential workplace exposures.

This page left intentionally blank

Supporting Technical Information

Evaluation of Occupational Exposures to Illicit Drugs at Forensic Sciences Laboratories

HHE Report No. 2018-0116-3370

March 2020

Section A: Workplace Information

Building

Each of the seven CSUs we visited was housed in a larger building with other law enforcement or forensic science activities. Each CSU had one laboratory area where evidence was handled and analyzed and one or more office areas where employees worked at desks and finished analytical reports but where no evidence was handled. At most of the CSUs, the office areas were separated from the laboratory areas by one or more doors, however, the exceptions are noted below.

- Laboratory A was built in 2001 and was designed to be dedicated laboratory space. This laboratory had seven variable air volume chemical hoods and a dedicated ventilation system solely for the laboratory space.
- Laboratory B was built in the 1970s and converted to a forensic laboratory in 1977. This laboratory had three constant air volume ventilation chemical hoods but did not have a separate ventilation system solely for the laboratory space.
- Laboratory C was built in the 1950s and converted to a forensic laboratory in 1983. This laboratory had one constant air volume chemical hood and a separate ventilation system solely for the laboratory space. The CSU office spaces were not completely separated from the laboratory spaces. One office area, containing cubicles and a refrigerator, adjoined the laboratory area with no separating walls or doors. Another office area was separated by at least one door. One private office had a laboratory benchtop with analytical equipment and chemicals where evidence was analyzed as well as a desk for computer use.
- Laboratory D was built in 1975 and was designed to be dedicated laboratory space. This laboratory was renovated in 2010 and had two constant air volume chemical hoods. It did not have a separate ventilation system solely for the laboratory space. There was a separate office area, but employees typically did their writing at their laboratory workspace. One private office was in the laboratory.
- Laboratory E was built in the 1970s and converted to a forensic laboratory in 2014. This laboratory had seven variable air volume chemical hoods and a separate ventilation system solely for the laboratory space.
- Laboratory F was built in 1989 and was designed to be dedicated laboratory space. This laboratory had three constant air volume chemical hoods and a separate ventilation system solely for the laboratory space. The office area was located within the same room as the laboratory, separated from the benchtop areas by a wall.
- Laboratory G was built in the 1950s and converted to a forensic laboratory in 1989. This laboratory was renovated in 2000 and had three constant air volume chemical hoods. It did not have a separate ventilation system solely for the laboratory space.

We visited the laboratories during the first site visit in August 2018. According to information provided by state police management representatives, an eighth CSU was converted to a forensic laboratory in 2009 and then renovated in 2015. We did not visit this laboratory because of logistical issues. The eighth CSU had one variable air volume ventilation chemical hood and a dedicated ventilation system solely for the laboratory space. We conducted follow-up site visits at four CSUs: A, B, C, and D. We chose to visit these for additional evaluation after considering the typical composition of the evidence accepted, number of employees, and findings of preliminary analyses performed by direct reading instruments.

Employee Information

- At the time of our first visit, 33 forensic scientists, forensic technicians, and laboratory managers worked across the seven CSUs (42 worked across all eight CSUs).
- Each CSU had a supervisor who reviewed casework reports and analyzed some casework evidence. The remaining chemists analyzed casework evidence and wrote reports in office spaces. At Laboratory D, one chemist was accepting and inventorying evidence for all the forensic units during our follow-up visit instead of analyzing casework in the CSU.
- All nonsupervisory employees were members of the Service Employees International Union.
- Each laboratory operated a single shift Monday through Friday, and employees worked 8–10.5 hours per day. Voluntary overtime hours were available to employees. The length of the workweek ranged 4–5 days depending on each employee's schedule.
- Among the 31 employees who participated in medical interviews during our first visit, the median age was 37 years (range: 23–56 years), and the median job tenure was 9 years (range: 1 month–28 years).

Process Description

- Suspected illicit drug evidence collected by law enforcement submitting agencies was brought to the facility evidence receiving area by submitting agency representatives.
- Evidence receiving personnel evaluated the packaged evidence in the evidence receiving area to ensure that it was packaged according to facility requirements. Evidence, in most cases, had to be in sealed packages with accompanying submission paperwork. Evidence receiving personnel were not allowed to accept needles, except in very limited circumstances with prior approval from state police management representatives.
- Inappropriately packaged evidence was rejected and submitting agencies were advised on how to repackage the evidence for submission.
- Appropriately packaged evidence was logged in by evidence receiving personnel and suspected illicit drug evidence was assigned to a forensic chemist for analysis. The evidence was kept in the drug vault until the forensic scientist collected it for analysis purposes.

- Forensic scientists analyzed suspected illicit drug evidence in the controlled substance laboratory. The specific types of analyses performed were dictated by the evidence being evaluated. In general, forensic scientists visually inspected the evidence packaging and contents, measured gross weights that included the packaging materials, measured net weights without the packaging materials, and performed two tests to confirm the identity of evidence. Many drugs underwent colorimetric testing, followed by extraction and gas chromatography-mass spectrometry, infrared analysis, or microscopic analysis. Laboratory D had a handheld Raman spectrometer that had been validated by the forensic chemists for identification of nine controlled substances at the time of our second visit. This device would be used by forensic scientists at Laboratory D to analyze a substance suspected to be one of these nine controlled substances through the packaging material without opening the packaging. If the evidence needed to be used for a trial, the evidence would undergo full analysis. The handheld Raman spectrometer was validated for cocaine, methamphetamine, heroin, diazepam, tramadol, morphine, oxycodone, amphetamine, and 3,4-methylenedioxymethamphetamine (MDMA).
- Forensic scientists summarized their methods and the results of their analyses in final reports. These reports were written on a computer either in the controlled substances unit laboratory or in administrative areas outside of the laboratory.
- Upon completion of an analysis, the forensic scientists repackaged the evidence and returned it to the evidence receiving area.
- Evidence receiving personnel documented the returned, repackaged evidence, and notified the submitting agency that the evidence was ready for them to pick up.
- Each laboratory has an annual safety audit by the state police industrial hygienist.
- Weighing practices (e.g., weighing at all, taking net or gross weights) for drug evidence depended on the associated criminal charge.

Section B: Methods, Results, and Discussion

Our objectives were as follows:

- Evaluate the routes and extent of work-related exposure to cocaine, fentanyl, heroin, and methamphetamine among forensic scientists, forensic technicians, and laboratory managers working in the CSUs.
- Identify controls to protect forensic scientists, forensic technicians, and laboratory managers from exposure to controlled substances.
- Evaluate the prevalence of work-related symptoms among forensic scientists, forensic technicians, and laboratory managers, and identify factors that may be contributing to the identified symptoms.

Methods: Health and Safety Program and Document Review

We reviewed safety and health program documents including the forensic sciences division health and safety manual, the respiratory protection program documents, the controlled substances procedures manual, a powder narcotic testing policy memo released in March 2018, safety data sheets (SDSs) for chemicals used in the CSUs, safety surveys and communications sent to CSU employees, opioid intoxication training, naloxone training materials and inventory records, and Occupational Safety and Health Administration (OSHA) Form 300 Log of Work-Related Injuries and Illnesses for the period of 1/1/2013–8/3/2018.

In addition, we reviewed records of casework performed by CSU employees in the 2 weeks that preceded our second visits to the CSUs A, B, C, and D. We also reviewed available facility floor plans, reports of recent maintenance performed on CSU laboratory ventilation chemical hoods, and the results of surface sampling performed in each of the eight CSUs in 2018 to evaluate for surface contamination.

Results: Health and Safety Program and Document Review

The safety manual provided administrative protocols aimed to reduce employee exposure to the substances being tested. Where state law dictates sentencing based on the total weight of certain drugs or the number of plants, chemists were supposed to weigh or count substances until the state weight threshold had been exceeded. The remaining units or items were to be left intact and not weighed. The "Controlled Substances Safety Plan" within the manual required that clean paper be used to cover the work surface area where drug evidence was inventoried, examined, transferred, or sampled. It also stated that a new clean piece of paper be used for each new or unrelated item of evidence.

Several forensic sciences division policies required employees to wash their hands thoroughly with soap and water after working with hazardous materials, handling chemicals, before leaving the laboratory, and before eating, drinking, smoking, or applying cosmetics.

Computers, laptops, and computer accessories were not to be moved to or from the office and laboratory workstations to prevent cross-contamination with controlled substances outside the CSUs. When computers were brought into the CSU, they were to be kept closed and physically separated from work areas, not be used or held while wearing gloves, and be cleaned before being taken out of the CSU.

The "Food and Drink Policy" stated that food and drink should not be stored or consumed in any laboratory analytical or processing area. It further stated that eating, drinking, and applying cosmetics in drug evidence storage areas and all areas with chemicals present were prohibited.

Forensic sciences division personal protective equipment (PPE) policy required gloves to handle open or unsealed drug evidence items. The policy required gloves, safety glasses, and laboratory coats during the active examination of drug casework. The PPE policy also required an approved and fitted N95 filtering facepiece or half-mask elastomeric air purifying respirator during active handling and examination of drug materials that were in a form that could become airborne or create a respiratory hazard (e.g., loose powder, dust, particulates, or spores). While handling powder casework, PPE was required to cover any exposed skin on hands and forearms.

The PPE and other division policies allowed for the use of either disposable nitrile or latex gloves when handling hazardous chemicals. In January 2017, the forensic sciences division issued a survey asking respondents to list any disadvantages they had experienced related to latex glove use. Among the 98 responses to this question, 20 involved reports of skin irritation or allergies related to wearing latex gloves. The only response to this question that was more common than reports of skin irritation or allergies were complaints that the latex gloves tore more easily than the nitrile gloves did.

The organization's respiratory protection program contained requisite components, including designating program responsibilities, an exposure assessment requirement, initial medical clearance, initial and annual fit testing, annual respiratory protection training, and seal checks upon use. The program did not explicitly list which employees were required and not required to be fit tested in the organization. According to the program, N95 filtering facepiece respirators should be changed every 8 hours and air purifying respirators should have cartridges replaced after 8 hours of continuous use or when the respirator user detects chemical breakthrough (e.g., taste, smell, irritation). When at the site, there were no obvious methods of tracking in-use time for air purifying respirators. CSU chemists were fitted with N95 filtering facepiece respirators using a qualitative saccharine test by the department industrial hygienist. They were fitted with half-mask elastomeric air purifying respirators using a quantitative fit test.

The "Health and Safety Committee" document outlined a health and safety committee comprised of a health and safety officer and a laboratory safety officer from each laboratory that meets regularly to review health and safety policy issues and makes recommendations for changes as needed. Discussions with employees and laboratory management representatives indicated that not all CSUs had representatives on the health and safety committee.

The health and safety manual also dictated that each laboratory appoint a laboratory safety officer who was provided time for their assigned activities. The laboratory safety officer was to monitor a variety of health and safety equipment monthly, including eyewashes and safety showers, automatic external defibrillators (AEDs), first aid kits, and opioid overdose kits. The state police health and safety officer reviewed the testing reports. The manual did not detail the training requirements for the laboratory safety officer.

Review of the OSHA Logs for the period of 1/1/2013–8/3/2018 showed one injury reported among CSU forensic scientists, forensic technicians, and laboratory managers. This injury was a musculoskeletal injury that occurred outside of the laboratory while moving heavy items.

Review of the cumulative results of surface sampling (n = 138 samples) at the eight CSUs performed in 2018 demonstrated laboratory surface contamination with a diverse array of controlled substances. Cocaine and heroin were detected most frequently, followed by methamphetamine and fentanyl. We did not directly compare the amounts found in these surface samples to our sampling results because of differences in the two sampling methods.

Methods: Observations of Work Processes, Practices, and Conditions

We evaluated the following in all seven CSUs we visited:

- Workplace conditions and work processes and practices.
- Ventilation chemical hoods' face velocity and airflow between laboratory areas and common areas using ventilation smoke.
- Employee use of PPE.

Results: Observations of Work Processes, Practices, and Conditions

Workplace Conditions and Work Practices

In all laboratories that we visited, controlled substances evidence dropped off by a submitting agency was inspected to ensure that it met evidence packaging requirements. Some CSU laboratories received evidence via the postal service inside an envelope or box. Upon delivery to these laboratories, the receiving evidence technician opened the envelope or box to inspect the evidence for compliance with packaging submission requirements. Evidence technicians informed us that they did not always wear gloves when opening these envelopes or boxes.

Although laboratory policy stated materials such as computers or paperwork should not be transported between laboratories and nonlaboratory spaces, technology allowing compliance with this policy was still being introduced and was not standard in all laboratories at the time of our visits. In some laboratories, paperwork and laptop computers were moved between the laboratories and office report writing areas. For example, in Laboratory B and others, laptops had to be transferred from laboratory docks to office docks to continue work. At Laboratory F, the information technology infrastructure had been adopted to limit this practice. At most laboratories, analytical output was paperless and viewed digitally, reducing the material that was transferred between laboratory and office areas. At Laboratory B, analytical output was printed, scanned, and saved to an internal network folder. The hardcopy outputs and submission paperwork were carried between the laboratory and office areas. At Laboratory D, all work including analysis and report writing was completed in the laboratory space and neither computers nor paperwork were transferred.

Evidence was handled by chemists exclusively in the laboratory areas during our site visits. They measured the net weight of almost all substances they analyzed. Chemists often put a piece of paper underneath items of evidence when those items were removed from outer (law enforcement) packaging (Figure B1). The pieces of paper varied in size and bench coverage.

Figure B1. Most employees laid paper under the casework evidence to prevent drug contamination of the bench. Some employees used large sheets, as pictured here. Some employees used small sheets of paper that just fit underneath the evidence itself. Photos by NIOSH.

At Laboratory A, non-CSU forensic laboratory workers discharge firearms into a water tank in a room adjacent to the CSU. Employees and management reported that these activities were not often announced and have caused chemists to be startled while they sampled and analyzed evidence.

Cleaning

Laboratory cleaning procedures were explicit in the procedure manual for tasks performed by the chemists. For routine laboratory cleanups, chemists were to wipe debris off surfaces, including lab benches, then spray with a 2% hydrogen peroxide mixture and wipe the bench with a single use paper towel. Balance plates were supposed to be cleaned of spills and debris after every use, when obviously dirty, and "between handling potentially toxic substances." For powder spills, chemists were to prepare and spray a sodium percarbonate solution onto the spilled powders. Sodium percarbonate solutions are typically prepared from OxiClean® powders. What was considered a spill was at the discretion of the chemist. Small amounts of drugs fell on balances and benchtops, but it was not clear if the protocols should be used or not. There were no obvious or high-volume spills during our visit. We observed hydrogen peroxide solutions and sodium percarbonate powders available at most, but not all laboratories.

Laboratory A chemists used methanol, water, and PDI Sani-cloth® Plus disinfectant cloths to clean work surfaces; we did not see hydrogen peroxide cleaning solution available in the laboratory. The disinfectant cloths contain 10%–20% isopropanol, < 5% 2-butoxyethanol, 0.125% of both quaternary ammonium chlorides and other ammonium chlorides, and 75%–85% "nonhazardous" components, like water, according to the wipe safety data sheet. Laboratory B, D, E, and F chemists used primarily methanol to clean laboratory surfaces and tools during our visit, but also had commercial 1.4% hydrogen peroxide solution (Clorox Healthcare®) available for cleaning. Laboratory C chemists primarily used methanol for bench and tool cleaning. They also had, and chemists used, Clorox® disinfecting wipes. A spray bottle with hydrogen peroxide solution (concentration not labeled) was available for cleaning, but we did not see it being used during our visit. Laboratory G had a household Lysol® bathroom cleaner containing 0.88% hydrogen peroxide and Envirocide® disinfectant (17.2% Isopropanol, 1%–5% 2-butoxyethanol, and 0.28% diisobutylphenoxyethoxyethyldimethylbenzyl ammonium chloride) for routine surface cleaning and OxiClean for spills.

We observed one employee use a brush to wipe away suspected controlled substances that spilled on a balance while the net weight was being measured for a piece of evidence (Figure B2). In addition, most laboratories had brooms or handheld brushes for cleaning. One laboratory had posted a weekly laboratory sweeping schedule.

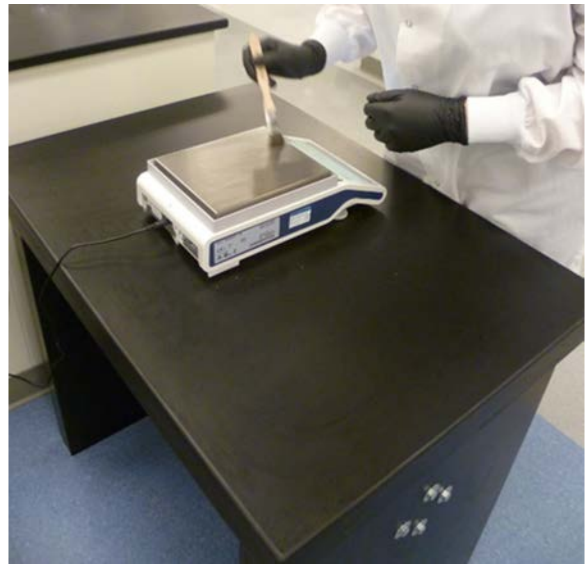

Figure B2. A chemist brushes a spill from a balance in a laboratory. Dry cleaning methods, especially for visible materials, can cause aerosolization. Photo by NIOSH.

We noted that some, but not all, laboratory chairs were upholstered with porous fabric that is difficult to clean, rather than chairs that are nonporous and wipeable.

Use of Raman Spectrometer

Laboratory D used a handheld Raman spectrometer (Thermo Scientific™ TruNarc™ Handheld Narcotics Analyzer) to analyze evidence through clear packaging for a preliminary assessment that was sent to the submitting agency. Of the four drugs we measured in this evaluation, this method was utilized for cocaine and methamphetamine. The method was also validated by the laboratory for heroin but was not frequently used for preliminary analysis because of the risk of false negatives for this analyte. The tool was not used to analyze evidence for fentanyl. The tool was validated by the laboratory system for a variety of drugs besides the ones assessed in this evaluation. If the case required a full analysis, then the evidence would undergo a full analysis before the assigned court date.

Ventilation Chemical Hood Performance and Airflow

All seven laboratories we visited had ventilation chemical hoods. Extraction solvents, other chemicals, and liquid chemical waste were stored in bulk in the hoods. Ventilation hood workspace availability for chemists varied by laboratory. At the newer laboratories, chemical hood space was widely available: Laboratory A had seven hoods and Laboratory E had nine hoods. Space was limited in older laboratories: Laboratory B had three hoods (two in use for casework), Laboratory C had one hood, Laboratory D had two hoods, Laboratory F had three hoods, Laboratory G had three hoods. Laboratory C had the worst hood to employee ratio, with seven CSU staff and one chemical hood.

According to management, any net (without packaging) weights should be taken in the ventilation chemical hoods; however, during our site visits, net weights were generally taken at a personal bench scale or a common area scale.

During our first visit to each laboratory, we found that 10 of the 16 (62%) chemical hoods we assessed did not meet ANSI/AIHA laboratory ventilation guidelines of an average face velocity of 80–120 feet per minute (fpm) [ANSI/AIHA 2012]. Laboratories A and E were the only facilities where all the chemical hoods met these guidelines. Hood velocities were both lower and higher than the range considered acceptable under the standard. At Laboratory G, two of the hoods average velocities were extremely high (325 fpm and 248 fpm). Chemists reported that the airflow in these hoods had aerosolized powders and weigh papers in the past, so they had to be careful when handling materials in the chemical hoods.

Ventilation chemical hoods in some of the laboratories were crowded (Figure B3). In some hoods, containers blocked the slots that are designed to ensure even airflow across the hood face, creating areas of low or no velocity across the hood face. We measured areas of no or low ventilation (dead spots) in one hood at Laboratory F.

Figure B3. Some laboratories had chemical hoods that were crowded with bulk chemicals, waste containers, paperwork, or discarded materials. Pictured here, discarded used gloves crowd a workspace in a chemical hood. Photo by NIOSH.

The laboratories we visited were generally negatively pressurized relative to hallways or office areas, with a few exceptions. Laboratory A was positively pressurized during both visits, and Laboratory B was positively pressured relative to the exterior only during the first visit. The remainder of the laboratories were negatively pressurized to adjacent areas during our visits.

Observed Employee Use of Personal Protective Equipment

We observed widespread use of nitrile gloves by employees while they handled evidence. Based on their own preferences, employees first donned and changed gloves at different points in the case analysis process: within a case, between cases, and after opening exterior (submitting agency) packaging before opening interior packaging.

Some employees reused gloves within a case, removing them to work on a keyboard and putting them back on. While most employees discarded gloves into trashcans, we observed significant accumulation of used gloves in a workspace (Figure B3). During our site visits, we observed latex gloves in evidence receiving areas and at least one laboratory. It was reported that at least one employee in a forensic laboratory had experienced latex allergy, resulting in dermatitis on the hands. We observed employees use personal cell phones in the laboratories with and without gloved hands.

Each laboratory had policies about where employees could and could not wear gloves. We observed labels on phones, doors, keyboards, and analytical equipment. For the most part, employees seemed to understand and comply with the labels, but we observed a few lapses: using gloves on a "nonglove" laboratory phone, wearing gloves into the instrumentation room, and using a keyboard with gloved and ungloved hands. These instances offered opportunities for drug transfer from used gloves to ungloved hands.

Almost all employees wore safety glasses while in the laboratories. We observed some employees wearing personal prescription eyeglasses without side shields. During our first site visit interviews, some CSU employees reported difficulties obtaining prescription safety glasses or receiving safety glasses that did not have the correct prescription.

We observed used N95 filtering facepiece respirators being kept in laboratory drawers or on shelves for future use (Figure B4). We also observed half-mask elastomeric air purifying respirators with cartridges attached being stored in drawers and on shelves (Figure B4).

Figure B4. Respirators stored inappropriately in laboratories. Photos by NIOSH.

Employees wore laboratory coats in the laboratory spaces, as required. Some laboratories did not use a coat rack, and coats were placed on other furniture or equipment (like carts) before leaving the laboratory (Figure B5). Laundry service for laboratory coats was provided, but the laundering schedules varied by laboratory and employee preference. Management provided scrubs for employees for use in the CSUs when requested.

Figure B5. Laboratory coat storage availability and practices varied across the CSUs. Photos by NIOSH.

We did not see employees tucking their laboratory coats into their gloves to prevent exposed skin on the wrists and arms. We observed both loose and tight cuffed laboratory coats. One employee wore the same glove throughout the day inside and outside the laboratory during our visit.

Methods: Exposure Assessment

Air Sampling

We took personal air samples for 18 of the 21 chemists present at CSUs A, B, C, and D during our second visit. We sampled for cocaine, fentanyl, heroin, and methamphetamine for 53 to 149 minutes using 25-millimeter glass fiber filters in conductive cassettes attached to pumps drawing air at 2 liters per minute. The other three chemists declined to participate in personal air and handwipe sampling. A series of two to four samples comprised an employee's full shift. We calculated a time-weighted average (TWA) concentration using the employee's individual sample data for each of the four target drugs. For results under the reporting limit, we used the reporting limit divided by the square root of 2 to impute censored data for individual samples when calculating the geometric mean of the full-shift TWA exposures [Hornung and Reed 1990].

All samples (air, handwipe, and surface) were shipped cold to the analytical laboratory. At the laboratory, the samples were extracted in the cassette to prevent wall losses using a water and methanol mixture. The samples were analyzed via ultrahigh performance liquid chromatography with triple quadrupole mass spectroscopy detection. The laboratory reporting limit was 1 nanogram (ng) per sample for each of the four drugs analyzed for both air and wipe samples. Below this amount, the drug was either not detected at all or too little drug was in the sample to be precisely quantified, even by very sensitive analytical methods. These samples are referred to as "not quantifiable" or NQ. For 5 of the 18 chemists, one of the samples that comprised their full-shift TWA concentration exceeded the 120-minute sample limit recommended by the analytical laboratory. The laboratory indicated that based on their internal stability testing, exceeding this limit could increase the uncertainty of the heroin and fentanyl air concentrations for these individuals.

We noted the case numbers that chemists worked on during our visits, and management provided the list of the confirmed drugs in each of those cases. For cocaine, heroin, and methamphetamine, we compared the personal full-shift air concentrations for those who worked with evidence confirmed to contain the drug to the concentrations for those who did not work on cases containing that drug. We compared the air concentrations of heroin, methamphetamine, and cocaine between the two groups using a one-tailed Mann–Whitney *U* test with significance established at $\alpha = 0.05$. We did not test this relationship for fentanyl exposures as only 2 of 18 chemists had quantifiable fentanyl air exposures. Full-shift fentanyl exposures were compared with an occupational exposure limit (0.1 microgram [μg] per cubic meter) established by a fentanyl manufacturing company [Van Nimmen et al. 2006].

Handwipe Sampling

We took preshift and postshift handwipe samples of 18 forensic laboratory chemists for cocaine, fentanyl, heroin, and methamphetamine. Prior to work in the laboratory, we instructed employees to wash their hands with soap and water thoroughly for 20 seconds after which we took the preshift handwipe sample to determine prelaboratory work amounts. Employees were asked to wash hands as they normally would during their work shift. Postshift handwipe samples were taken when the employee ended work in the laboratory and before they washed their hands for the last time. We sampled the palm side of both of each employee's hands using a swab wetted with methanol. The fraction of the total amount of each analyte on the hands that was removed (recovery) during wipe sampling has not been characterized.

For each drug, we compared the personal handwipe results for those who worked with evidence confirmed to contain the drug to the results for those who did not work on cases containing that drug. We compared the handwipe amounts of the two groups using a one-tailed Mann–Whitney *U* test with significance established at $\alpha = 0.05$. We are not aware of occupational standards or guidelines regarding limits on handwipes for cocaine, fentanyl, heroin, and methamphetamine.

Surface Sampling

We sampled a total of 50 surfaces at CSUs A, B, C, and D for cocaine, fentanyl, heroin, and methamphetamine using a swab wetted with methanol. This included twenty-five work benches, four gloved hands, three chemical hood workspaces, one balance, seven office desks, eight laboratory keyboards, and two areas near instruments. The sample area was 100-square centimeters (cm^2) (using a template) on all surfaces, except keyboards and gloved hands. We sampled approximately 100 cm^2 on keyboard surfaces. We sampled the palm side of both gloved hands for four employees at the end of sampling from a case. This was in addition to the samples taken of bare hands, described above.

Average surface recovery for the materials comprising laboratory benchtops, office desktops, and scale plates exceeded 70% using the swabs [Bureau Veritas North America 2018]. For other surfaces, like keyboards and gloved hands, the recovery ranges for these materials have not been characterized.

There are no occupational standards regarding limits on surfaces for cocaine, fentanyl, heroin, and methamphetamine set by the federal government or consensus organization. However, some companies and states have developed surface contamination limits. One company that manufactures fentanyl has suggested a draft limit of 1 μg fentanyl per 100 cm^2 [Van Nimmen and Veulemans 2004]. Some states have developed guidelines for remediation of contaminated spaces, like clandestine drug labs. The U.S. Environmental Protection Agency (EPA) has developed methamphetamine laboratory cleanup guidelines. According to the EPA, 25 states have developed recommended or required standards for methamphetamine remediation as of 2013. The state standards range from 0.05 to 1.5 μg per 100 cm^2, the most common being 0.1 μg methamphetamine per 100 cm^2 [EPA 2013]. California law provides limits for the clean-up of properties contaminated by illegal methamphetamine and/or fentanyl laboratories [California Legislature 2019]. The California law states that (1) property contaminated by illegal methamphetamine laboratory activity is safe for human occupancy if the level of methamphetamine on an indoor surface is $\leq$ 1.5 μg per 100 cm^2, and (2) property contaminated by illegal fentanyl laboratory activity is safe for human occupancy if the level of fentanyl on an indoor surface is "below the detection level." The law does not state what the detection level is.

Biomonitoring

During our return visits, we invited all employees working in the CSUs on case evidence (forensic scientists, forensic technicians, and laboratory managers) to participate in urine testing for cocaine, fentanyl, heroin, and methamphetamine. Urine testing was performed as another method to assess for exposure to these controlled substances among employees. Biomonitoring accounts for all routes of exposure: inhalation, ingestion, and dermal or mucous membrane absorption (percutaneous exposure is unlikely in this setting). Those participating provided a spot urine specimen at the end of their work shift on the day of our visit to their laboratory. At each laboratory where urine specimens were collected, participating employees collected their urine specimens in a single bathroom located outside of the laboratory. To assess for the potential of environmental contamination during collection and processing, we also collected a total of four synthetic human urine field blanks, one in each of the bathrooms that participating employees used to collect their individual urine specimens. The field blank consisted of synthetic human urine provided to NIOSH by the laboratory contracted to analyze the urine specimens.

The laboratory contracted to analyze the urine specimens used a liquid chromatography-tandem mass spectrometry method to measure the concentration of cocaine, benzoylecgonine (a cocaine metabolite), fentanyl, norfentanyl (a fentanyl metabolite), heroin, 6-acetylmorphine (a heroin metabolite), morphine (a heroin metabolite), hydromorphone (a heroin metabolite), and methamphetamine. The laboratory lower limits of quantification (LOQ) for the urine concentrations are listed in Table C1. Below this limit, the analyte either cannot be detected in the sample or is too low to be accurately quantified, despite the use of very sensitive laboratory methods. Urine concentrations of these substances equal to or below the respective LOQ were reported as NQ (not quantifiable).

Urine concentrations of these substances were compared with concentrations used as cutoffs for positive results for federal workplace drug testing when available [DHHS 2017]. The federal initial drug test cutoffs are listed in Table C1. There are no workplace exposure limits for these substances, and the urine tests do not have reference ranges.

Review of Cocaine, Fentanyl, Heroin, and Methamphetamine Casework

Following our visits, we requested records of cocaine, fentanyl, heroin, and methamphetamine casework that was performed on the days of our visit and for all workdays 2 weeks prior to our return visit. Specifically, we reviewed casework information that included analysis location, forensic scientist performing the analysis, dates of the analysis, and identification, mass, and form of the controlled substances analyzed. In addition, we recorded the numbers of cases that chemists worked on during the day of our return visits when we conducted air and handwipe sampling. We cross referenced these cases with the list provided to us from the laboratories. We compared the data about casework performed on the days of our visit with the results of the air and handwipe samples collected on those days.

The urine testing for the target drugs and their metabolites may have captured exposures to the target drugs that occurred on the days of our visit and/or over the days that preceded our return visits. Table C2 shows the estimated urine half-life (i.e., the time it takes for the concentration of a given substance to decrease by half) and urine window of detection times for each of the analytes included in the urine testing. The urine windows of detection times shown in Table C2 are based on laboratory methods that are less sensitive than the methods used for urine testing in this evaluation. Therefore, the urine window of detection times for our testing are likely longer than the times listed in the table. We chose to review casework on the days of our visit as well as all workdays over the 2 weeks that preceded each of our return visits to better understand possible exposures to cocaine, fentanyl, heroin, and methamphetamine that may have contributed to the urine testing results. Because some cases involved mixtures of controlled substances, and masses were not taken for cases involving residues, liquids, capsules, and tablets or analyzed through packaging material via handheld Raman spectrometer, exact amounts of the target drugs in the casework handled over the period of interest could not be determined.

Results: Exposure Assessment

Air Sampling

Eighteen employees participated in air sampling at the four laboratories during our second visit. Between two and four consecutive samples comprised a full-shift sample on the sampling day (216 to 500 minutes). For one employee, one sample was not analyzed because of pump failure, so one hour of the employee's shift was not captured during sampling. At Laboratory A, sampling started about one hour after employees arrived at the laboratory, but employees had not begun handling casework and remained in the office space until air sampling started.

Minimum, maximum, and geometric mean full-shift TWA exposures are in Table C3. Table C4 contains the TWA full-shift concentrations for all participating employees. None of the full-shift fentanyl exposures exceeded an occupational exposure limit established by a fentanyl manufacturing company (0.1 μg per cubic meter) [Van Nimmen et al. 2006]. The other analytes, cocaine, heroin, and methamphetamine do not have established occupational exposure limits. Of the 18 employees, 10 handled cocaine-containing evidence, 9 handled fentanyl-containing evidence, 9 handled heroin-containing evidence, and 12 handled methamphetamine-containing evidence.

We looked at the relationships between confirmed substances in employees' casework and the results of their personal air samples. Seven employees who did not work on casework containing cocaine had cocaine in their personal air samples. The same was true for one employee who did not work on fentanyl-containing cases, one employee who did not work on heroin-containing cases, and three employees who did not work on methamphetamine-containing cases.

Conversely, two employees who worked on casework containing cocaine did not have cocaine in their personal air samples. Again, the same was true for two employees who handled casework containing heroin and eight who handled casework containing fentanyl. All employees who worked on casework containing methamphetamine had methamphetamine in their personal air samples.

For methamphetamine ($P < 0.001$) and heroin ($P = 0.003$), air exposures to these drugs were higher for employees who worked on casework confirmed to contain the drug than those who did not. We found no significant difference in cocaine exposures between employees who handled casework containing cocaine and those who did not ($P = 0.38$).

Handwipe Sampling

Table C5 shows handwipe sampling results for employees at the four laboratory locations. Notably, more than half of the employees had methamphetamine and cocaine on their hands before working in the laboratory, after washing their hands. All postshift handwipe samples for each of the 18 employees collected had higher amounts of a given analyte compared with preshift handwipe samples, unless both samples did not have quantifiable amounts.

All 18 postshift handwipe samples had cocaine (range: 4.2–1,500 nanograms [ng] per sample) compared with 9 preshift handwipe samples (range: NQ–24 ng per sample). Thirteen of 18 postshift handwipe samples had fentanyl (range: NQ–750 ng per sample) compared with one (1.2 ng) preshift handwipe sample. Seventeen postshift handwipe samples had heroin (range: NQ–610 ng per sample) compared with two preshift handwipe samples (range: 1.0–2.4 ng per sample). All eighteen postshift handwipe samples had methamphetamine (range: 1.3–658 ng per sample), and 10 preshift handwipe samples had an amount (range: NQ–20 ng per sample).

Handwipe amounts of methamphetamine ($P = 0.003$) and heroin ($P = 0.02$) were significantly higher for employees who worked on casework confirmed to contain the drug than those who did not. There was no significant difference in cocaine exposures between employees who handled casework containing fentanyl ($P = 0.39$) and cocaine ($P = 0.55$) than those who did not.

Surface Sampling

Table C6 shows surface wipe sampling results for surfaces at the four laboratories. All eight surface samples collected on keyboards had cocaine (range: 1.6–5.5 µg per sample), heroin (range: 0.026–3.4 µg per sample), methamphetamine (range: 0.054–8.6 µg per sample), and fentanyl (range: 0.005–0.47 µg per sample).

Of 27 surface samples collected on lab benches, all had cocaine (range: 0.04–6.6 µg per 100 cm^2) and methamphetamine (range: 0.009–59 µg per 100 cm^2); 26 had fentanyl (range: 0.0015–0.42 µg per 100 cm^2), and 23 had heroin (range: 0.0022–1.9 µg per 100 cm^2).

Cocaine was found on all seven report desk samples (range: 0.0032–0.13 µg per 100 cm^2). Six report desks had heroin (range: 0.0013–0.0051 µg per 100 cm^2), and five desks had methamphetamine (range: 0.0011–0.047 µg per 100 cm^2). None of the report desks had fentanyl.

None of the report desk samples exceeded the most common state remediation guideline of 0.1 µg methamphetamine per 100 cm^2 [EPA 2013]. Twenty of the laboratory benches, chemical hood work areas, and instrument bench samples exceeded this guideline. Five of the eight keyboard samples exceeded this guideline. These standards are not occupational standards but can he helpful in the absence of those standards. The EPA notes that these standards are thought to be health-protective, despite being developed with feasibility and available technology in mind [EPA 2013; Colorado Department of Public Health and Environment 2005].

None of the surface samples exceeded a limit of 1 µg fentanyl per 100 cm^2 that one fentanyl manufacturer set [Van Nimmen and Veulemans 2004]. However, 26 of our 27 samples were above the detection limit of our method and therefore exceeded fentanyl surface limits as cited by the state of California in the "Methamphetamine or Fentanyl Contaminated Property Cleanup Act" [California Legislature 2019].

Biomonitoring

Among the 21 forensic scientists, forensic technicians, and laboratory managers working during our return visits, 18 participated in urine testing for the target drugs and their metabolites. A summary of the urine sampling results is shown in Table C1. Although 14 employees participating in testing had urine concentrations above the LOQ for one or more of target drugs or metabolites, none of these results approached available federal workplace drug testing cutoffs. None of these employees who participated in questionnaires reported any symptoms or health effects that they felt were related to handling illicit drugs at work in the 2 weeks that preceded our visit.

Among the nine employees with cocaine in their urine, five also had the primary cocaine metabolite benzoylecgonine in their urine. Two additional employees whose urine did not contain quantifiable cocaine had benzoylecgonine in their urine. All 11 employees with cocaine and/or benzoylecgonine in their urine had cocaine on surface wipe samples of their laboratory benchtops and had worked with cases containing cocaine in the 2 weeks that preceded our return visit. Ten of the 11 employees with cocaine and/or benzoylecgonine in their urine also participated in air and handwipe sampling. They completed a questionnaire and all of them had cocaine in their air samples and in postshift handwipe sampling.

Among the 12 employees with methamphetamine in their urine, all 12 had methamphetamine in surface wipe samples of their laboratory benchtops and had worked with cases containing methamphetamine in the 2 weeks that preceded our return visit. Among the 11 employees with methamphetamine in their urine who also participated in air and handwipe sampling and completed a questionnaire, all had methamphetamine in their air and postshift handwipe sampling. In addition, 11 of the 12 had worked with cases containing methamphetamine in the same work week as our visit.

One employee had fentanyl and norfentanyl, the primary fentanyl metabolite, in their urine. This employee had fentanyl in their laboratory benchtop surface wipe sampling and had worked with cases containing fentanyl in the same work week as our visit.

None of the urine samples contained heroin or its metabolites, even though 14 of 18 employees had handled casework containing heroin within the longest window in which the drug and its metabolites can be found post-exposure (4 days). Although attributing drugs and metabolites in urine to one or several individual work practices is not possible considering the small sample sizes and variable casework across employees, we identified several potential work practices that can contribute to drug exposures. All of the employees with one or more illicit drugs in their urine testing reported in the questionnaire one or more of the following work practices: (1) inconsistent use of nitrile gloves, eye protection, and/or laboratory coats while performing casework in the CSU; (2) inconsistent washing of hands prior to leaving the CSU; (3) sometimes eating in the CSU; and (4) regularly dry sweeping CSU floors, using compressed air for cleaning in the CSU, and/or wiping CSU surfaces with a dry cloth. Several employees reported occurrences of direct skin contact with one or more illicit drugs in the CSU.

Four employees did not have any drugs or drug metabolites in their urine. One of these employees did not open and analyze evidence during the exposure windows that could result in urine containing the drugs or drug analytes. Of the remaining three employees, all three also reported some of the non-ideal work practices listed above. Of note, all three of these employees reported always or "almost always" wearing nitrile gloves and reported changing gloves at least between every case. Two reported changing gloves between items in a case. Two reported working with suspected fentanyl or powdery cases in a chemical hood while the other employee did not use the chemical hood. All three employees reported not dry sweeping, emptying the trash, or using compressed air in the laboratory for cleaning. These employees also analyzed fewer total items (3 or 4) in the applicable exposure window that contained one or more of these four drugs than did employees who had at least one drug or drug metabolite in their urine (range: 0 to 23, median: 10).

Two of the field blank urine samples had cocaine concentrations above the laboratory LOQ (0.078 ng per milliliter [mL] and 0.065 ng/mL). None of the other analytes tested for, including the primary cocaine metabolite benzoylecgonine, were found in the field blanks.

The source of the cocaine found in those two urine field blanks is unknown. These results may represent evidence of small amounts of environmental cocaine contamination of the samples in the bathrooms where the samples were collected or in the administrative areas where the samples were prepared for shipping to the laboratory for analysis. The presence of the primary cocaine metabolite, benzoylecgonine, in five of the nine cocaine-positive samples, provides evidence for absorption and metabolism of cocaine among those employees (rather than environmental contamination during collection and processing).

Review of Cocaine, Fentanyl, Heroin, and Methamphetamine Casework

The number of cases analyzed over the 2 weeks preceding our visits that involved only cocaine ranged 26–68 cases across the four CSUs we visited during our second visits. Nearly all the 68 cocaine cases at the laboratory with the highest number of cases were analyzed through packaging via handheld Raman spectrometer. For cocaine cases where evidence was weighed, masses ranged 0.021–497.77 grams. This cocaine came in a variety of forms including different colored powders, chunky material, tablets, and crystalline material. One CSU handled two cases that involved a mixture of cocaine and heroin. These cases had masses of 0.07 grams and 0.552 grams.

Review of cases involving only fentanyl analyzed over the 2 weeks preceding our visit ranged 4–20 cases across the four CSUs we visited. For cases where the mass was measured, fentanyl masses ranged 0.01–323.7 grams. The forms of fentanyl included tablets and different colored powders. Fentanyl was often found mixed with other controlled substances with 44 total cases involving mixtures that included fentanyl. Of these cases, 36 involved mixtures of fentanyl and heroin. The remaining eight cases involved various mixtures of fentanyl with heroin, tramadol, methamphetamine, and/or morphine.

Among the cases involving only heroin analyzed in the 2 weeks preceding our visit, the case numbers ranged 2–14 cases. For cases where the mass of heroin was measured, the masses ranged 0.03–56.96 grams. The forms of heroin included different colored powders, chunky material, crystalline material, and solids. Like fentanyl, heroin was often found mixed with other controlled substances; 43 cases involved mixtures that included heroin. In addition to the 36 cases involving fentanyl and heroin noted above, 7 cases involved various mixtures of heroin with fentanyl, tramadol, methamphetamine, and/or cocaine.

The range of methamphetamine-only cases analyzed over the 2 weeks preceding our visit ranged 2–117 cases across the four CSUs. At one of the CSUs, 13 of 16 methamphetamine-only cases were analyzed through packaging material via handheld Raman spectrometer. For cases where the mass was measured, methamphetamine masses ranged 0.004–138.09 grams. The methamphetamine in these cases came in a variety of forms including different colored powders, crystalline or chunky material, tablets, and liquid. Methamphetamine was less commonly mixed with other controlled substances, with a total of seven cases involving various mixtures of methamphetamine with heroin; fentanyl; MDMA (3,4-methylenedioxymethamphetamine); amphetamine; oxycodone; and/or morphine.

Methods: Employee Health Assessment

Confidential Medical Interviews

During our first visit, we invited all forensic scientists, forensic technicians, and laboratory managers working across the seven laboratories to participate in confidential semistructured medical interviews. Interviews covered basic demographics, work history and practices, health and safety concerns, and possible work-related health effects or controlled substance direct exposure incidents during the 3 months preceding our visit.

Written Questionnaires

We used the results of the interviews to help design the written questionnaire that we administered on our return visits. We invited all forensic scientists, forensic technicians, and laboratory managers working across the four laboratories we visited on these return visits to complete a written questionnaire. Questionnaires covered basic demographics, work history and practices, training history, possible work-related health effects, controlled substance direct exposure incidents, past medical history, social history, and health and safety concerns.

Results: Employee Health Assessment

Confidential Medical Interviews

During our first visit, 31 of 33 forensic scientists, forensic technicians, and laboratory managers participated in confidential medical interviews across the seven laboratories we visited. Employees frequently worked in more than one area, including CSUs, office areas, and instrument rooms. The most commonly reported job tasks included controlled substance case analysis (n = 27), testifying in court (n = 21), and laboratory cleaning (n = 12).

When asked about direct skin, respiratory, or mucous membrane exposure to suspected or known controlled substances at work, five interviewed employees reported one or more definite or possible incidents of this nature in the 3 months preceding our visit. A variety of controlled substances were involved in these incidents including psilocin, methamphetamine, and cannabis. Only one of these incidents was reported. The reason for nonreporting of these incidents was employee's feeling that the incident(s) were not significant enough to report. No symptoms were reportedly associated with the incidents.

Separate from these incidents noted, three employees reported symptoms that they thought could be related to working with controlled substances over the 3 months that preceded our visit. Two additional employees reported having symptoms while working in the CSU and being uncertain whether these symptoms were related to work in the CSU. Reported symptoms included a bitter taste in the mouth when handling some opioid cases, upper respiratory symptoms such as sinus congestion and headaches, skin rash, and tingling and numbness of the lips and/or mouth. The employee who noted the bitter taste attributed this symptom to possible adulterants such as quinine that may have been mixed with certain opioid cases. The employee who experienced the upper respiratory symptoms attributed these symptoms to plant material, especially moldy plant material. Three of the five employees with symptoms while working in the CSU had been evaluated by a medical provider for the symptoms. Only the employee with the upper respiratory symptoms received a diagnosis for the symptoms. This employee was told that the symptoms were likely due to allergies to dust, mold, or something in the plant material being analyzed.

Of the 31 interviewed employees, 12 reported no health and safety concerns related to working at the laboratories. Nineteen employees reported specific safety and health concerns, including the following:

- Poor air quality in the CSUs.
- Possible drug cross contamination between laboratory and nonlaboratory areas of the CSU.

- Inadequate PPE training and availability (including confusion about respirator use, donning, doffing, and care and maintenance).
- Inadequate communication surrounding the introduction of new policies, including concern of a large number of policy changes.

Written Questionnaires

During our return visits, 19 of 21 forensic scientists, forensic technicians, and laboratory managers working in the four laboratories we visited completed a questionnaire. Among the 18 responding employees who performed casework, the median number of cases analyzed over the 2 weeks preceding our visits was 23 cases (range: 4–80 cases).

Among the 18 employees who worked in a CSU, all reported participating in cleaning the CSU, and all reported cleaning their personal laboratory benchtop. Of these 18 employees, 12 reported cleaning their benchtop between cases or between evidence items within a case. Four employees reported cleaning their benchtop several times a day but not between cases, and one employee reported cleaning their benchtop weekly. When asked about specific cleaning practices, four responding employees reported dry sweeping floors, three reported dry wiping surfaces, and two reported using cans of compressed air for cleaning in the CSU. Other cleaning activities included wiping laboratory surfaces with water, methanol, ethanol, hydrogen peroxide, "provided cleaning agent," and "saniwipes" (Sani-cloths).

Table C7 shows the frequency of reported PPE use and hygiene practices over the 2 weeks preceding our return visits among employees completing a questionnaire. Responding employees reported inconsistent PPE use when handling controlled substances over this period with four employees reporting sometimes or never wearing a laboratory coat, six (32%) reporting sometimes or never using nitrile gloves, and twelve (63%) reporting sometimes or never using eye protection. Regarding glove use, one employee (5%) reported never wearing gloves and 5 (26%) reported wearing gloves sometimes. Among the 18 employees who reported using nitrile gloves at all, 16 reported changing gloves at least as often as after every case and 2 reported changing gloves several times a day but not after every case. Six responding employees had been provided prescription safety glasses by the forensic sciences division. Among these six employees, three (50%) reported problems with their prescription safety glasses which negatively impacted the use of the glasses. Of the 19 employees who completed a questionnaire, 12 (66%) reported not knowing when their laboratory coat was last laundered.

As shown in Table C7, 6 of 19 employees (32%) surveyed reported sometimes using a respirator. All six of these employees reported using their N95 filtering facepiece respirator. One of these six reported using their half-mask elastomeric air purifying respirator. The remaining 13 of the 19 employees surveyed reported never using a respirator when sampling and analyzing casework.

Four of nineteen employees (21%) surveyed reported only sometimes or never washing their hands before eating, drinking, or smoking, a risk factor for accidental ingestion of controlled substances. Furthermore, eleven of nineteen employees (58%) reported only sometimes or never washing their hands before leaving the laboratory, a practice that contributes to drug contamination in nonlaboratory spaces. The health and safety manual stated that employees should wash their hands after handling hazardous materials, which would include controlled substances. During workplace observations, we saw regular glove changes but infrequent handwashing throughout the workday or before leaving the laboratories among employees.

Four of the 19 surveyed employees said they never process evidence in a ventilation hood. Of the 15 employees who said they process evidence in a chemical hood, five (33%) said they had not processed any cases in a ventilation hood in the preceding 2 weeks, indicating that circumstances perceived to require the use of a chemical hood were relatively infrequent. CSU employees were asked under what circumstances they chose to work in the chemical hoods in their laboratories. Responses varied, but employees said they would work in chemical hoods with any cases involving any powders or large amount of powers, when they needed to do an extraction using a solvent, when a material contained suspected fentanyl, or when submitted evidence was smelly or moldy. No employee said they worked exclusively in the chemical hood when handling evidence.

We asked employees who completed a questionnaire whether they had received training in several different topics and whether they had suggestions for how training could be improved. Table C8 shows that nearly all responding employees reported receiving training on these topics. Suggestions for improvement included providing more hands-on and in-depth training in these topic areas in the future.

We asked responding employees whether they had experienced a variety of symptoms or health effects over the 2 weeks that preceded our second visits that they felt were related to handling controlled substances at work. Two employees reported uncertainty about whether symptoms they experienced while working in the CSU could be related to casework. One of these employees reported experiencing anxiety, sweating, and increased heart rate while working in the CSU, but noted that the medical provider who evaluated these symptoms did not feel they were related to workplace exposures. The second employee reported uncertainty about whether increased heart rate and lip numbness were related to working in the CSU but had not discussed the symptoms with a medical provider. The remaining 17 responding employees denied experiencing any of the symptoms or health effects at work over this period. A summary from the literature of examples of health effects consistent with severe cocaine, fentanyl, heroin, and methamphetamine toxicity is shown in Table C9.

In order to better understand exposures outside of work that could have impacted the urine testing for the target drugs and their metabolites, we asked about prescription or over-the-counter medications taken in the month preceding our visits and contact with controlled substances outside of work or intake of certain food or drinks in the 2 weeks preceding our visits. None of the medications listed were ones which would impact the urine test results. Four responding employees reported ingesting food containing poppy seeds in the 2 weeks preceding our visits. Although poppy seed intake can result in detectable concentrations of morphine in the urine [Rohrig and Moore 2003], none of the employees who reported eating poppy seeds in the 2 weeks preceding our visits showed morphine in their urine. No employees reported consumption of tea containing coca leaves, a drink that can cause detectable concentrations of urine cocaine and cocaine metabolites [Jenkins et al. 1996].

We also asked responding employees about health and safety concerns related to their work. One employee reported concern about the forensic sciences division training for administering naloxone in the event of an emergency. According to this training, if emergency medical services (EMS) providers were less than five minutes away, employees were advised to wait for EMS providers to arrive before administering naloxone in the event of an emergency involving a suspected opioid overexposure. We discussed this issue with the management official responsible for the naloxone use training and were informed that training materials had been updated to remove this restriction. One employee expressed concerns about poor ventilation and inadequate ventilation chemical hood maintenance in the CSU. Two other employees raised indoor environmental quality concerns such as poor air quality in laboratory facilities and dust coming from building ventilation vents in the CSU.

Discussion

None of the CSU employees at the laboratories we visited reported symptoms associated with any of the substances of concern in this evaluation. We found all four drugs—cocaine, fentanyl, heroin, and methamphetamine—in the air, on CSU employees' hands, and on work surfaces both inside and outside of the laboratories. Some employees had biological evidence of exposure to cocaine, methamphetamine, and fentanyl, as these drugs and their metabolites were found in their urine.

Biomonitoring is useful to assess cumulative exposure via all possible routes. Using air, hand, and surface wipe sampling, we found that employees are possibly exposed via inhalation, contact with mucous membranes, or through accidental ingestion. A less likely but possible route of exposure would be dermal absorption. These data, paired with the questionnaire data, show that exposure controls are not preventing drug exposure as well as they could. Our sampling results were above some of the available limits established for environmental clean-up purposes. However, it should be noted that these limits are not designed for occupational exposure purposes. Requirements of "nondetection" for fentanyl surface sampling cited in this report [California Legislature 2019] will be impacted by the increasing sensitivity of sampling methods to detect very small amounts of fentanyl. Further research on appropriate occupational exposure limits for these substances is needed.

Prudent occupational health practice calls for minimizing exposure to these substances because of the known hazards at higher levels of exposure and the unpredictable nature and origin of the evidence being handled. Prudent occupational health practice also calls for the handling of evidence as little as possible, implementing engineering controls, and developing emergency response policies that would reduce the likelihood of exposure and subsequent health effects in the event of an acute spill or exposure.

During our site visits, work practices that were inconsistent with the health and safety manual or that reflected misunderstanding of the programs created opportunity for hazardous drugs exposure. For example, filtering facepiece respirator use was infrequent and did not appear to follow the procedures outlined in the health and safety manual. Because of the variability in incoming evidence, scenario-based protocols would be an effective approach to writing guidelines. This means that guidance on what engineering controls and PPE should be used for a specific type of evidence would be useful. Guidelines should include clear policies for how and where employees can process evidence. For example, the testing of small amounts of evidence may be done on the desktop, but nontrace evidence or evidence from suspected traffickers should be sampled in a chemical hood or other ventilated enclosure.

We found that although staff reported training on respirator use and storage (17 of 19 employees surveyed), those work practices needed improvement. Laboratory coats were available to employees, and we observed good coat use. However, the irregular and infrequent laboratory coat laundering and inappropriate storage could contribute to ongoing contamination of employees' hands and surfaces in the laboratory and outside of the laboratory when the laboratory coats were moved.

Preshift handwipe samples were positive for cocaine and methamphetamine for more than half of the sampling participants. In a similar health hazard evaluation conducted in a forensic science laboratory, preshift handwipes samples had a similar rate of positive preshift handwipes and similar amounts for these drugs [NIOSH 2019]. The most likely explanation is contamination of multiple surfaces in the workplace (and possibly outside the workplace) contributing to hand contamination that was not completely removed by the prewipe handwashing. Our surface sampling in nonlaboratory work areas confirmed the presence of cocaine, methamphetamine, and heroin. We did not sample some commonly touched but infrequently cleaned surfaces, such as doorknobs. In an evaluation from 2011, a police department drug vault had lower amounts of methamphetamine on surfaces (maximum 0.079 μg/100 cm^2) and similar amounts of cocaine on surfaces (maximum 7.3 μg/100 cm^2) as those we measured in this evaluation [NIOSH 2011].

Several factors may have contributed to higher amounts in the postshift handwipes, including contaminated surfaces, evidence handling practices, unstandardized cleaning practices, and current hand washing practices. The hand contamination during work likely came through touching contaminated work surfaces (labeled both glove and no glove) and, for some, handling interior evidence packages. Analyzing wipes of internal evidence packaging (even when the package itself remains unopened) predicted contents with 92% accuracy using sensitive analytical methods, while wipe samples of the outer packaging (provided by the submitting agency) was a poor predictor with less than 50% accurate [Sisco et al. 2019a]. This suggests that employees should take care to handle evidence using precautions to protect skin (like gloves) and surfaces when removing evidence from external (law enforcement) packaging, even if it appears intact.

Cleaning practices varied both by laboratory and by employee. The staff at the laboratories we visited used a variety of cleaning materials: methanol, water, Sani-cloths, and hydrogen peroxide. Some of these methods have been studied in a limited context and others have not. The health and safety manual outlined both routine and spill cleaning practices based on research regarding controlling drug contamination in laboratories. Research on removing controlled substances from surfaces and equipment via physical removal or degradation is ongoing. One study demonstrated several cleaning protocols had greater than 97% removal efficiencies from surfaces including laboratory benches; the protocols included methanol, soap and water, OxiClean™, adhesive and methanol, and Dahlgren Decon solution [Sisco et al. 2019b]. Products that contain or generate peracetic acid may also be effective in the decontamination of fentanyl and carfentanil, but guidelines on amounts and durations have not been established [EPA 2018]. UV radiation and temperature may also be effective in degrading fentanyl [Reitstetter and Losser 2018]. The *EPA Fact Sheet for On-Scene Coordinators on Fentanyl and Fentanyl Analogs* describes strategies for decontamination and cleanup in various forms and on different surfaces [EPA 2018]. These cleaning studies have implications in both reducing workplace exposure to controlled substances and analytical integrity (by reducing the likelihood of unintentional sample contamination) in laboratories as analytical methods become more sensitive.

During the current opioid overdose crisis, many federal agencies and professional organizations have provided guidelines on keeping workers safe from fentanyl, its analogues, and other opioids through engineering controls, work practice changes, and PPE. The American Academy of Forensic Science (AAFS) published a position statement recommending control methods that follow the hierarchy of controls approach when handling and analyzing suspected synthetic opioids. These controls include implementing strict evidence acceptance protocols; using engineering controls such as evidence packaging, chemical hoods, and balance enclosures; and using work practices including good lab technique and housekeeping [AAFS 2017]. Additionally, the AAFS recommends implementing an emergency response plan that includes spill control, decontamination, first aid, naloxone use, and appropriate training on these safety protocols [AAFS 2017]. The American Society of Crime Laboratory Directors provides more specific recommendations. These include changing packaging/storage guidelines, updating laboratory practices, using alternative sampling devices (to test evidence without removing it from packaging), adopting a naloxone policy, and adding further training and education [American Society of Crime Laboratory Directors 2018].

Ideally, all evidence should be handled and analyzed in a chemical hood, and there should be one chemical hood for each chemist. However, the current laboratory configurations and the number of chemical hoods at each laboratory we evaluated does not allow this. Some chemical hoods had face velocities outside of the standard range, either above or below the recommended average face velocity of 100 fpm (range: 80–120 fpm). Face velocities lower than recommendations may be inadequate to capture contaminants. Face velocities higher than recommendations may cause airflow turbulence, which reduces the ability of the chemical hood to capture contaminants and may even cause contaminants to escape the hood. Higher than recommended airflow also results in higher electricity use and expenses while not improving capture efficiency. In this evaluation, the high face velocities we measured also make it difficult to work with or weigh powders inside the hood. Furthermore, for sampling powders or when balance sensitivity is important, a ventilation hood enclosure such as a powder hood should be used.

Chemical hood availability varied across the sites. Laboratory A had hood availability for all chemists, but Laboratories B, C, D, and F did not. We observed some chemists work more frequently inside the chemical hoods than others. The questionnaire responses and our observations revealed that chemists had different opinions when it came to working with evidence in chemical hoods or on laboratory benchtops. When employees can be exposed to high-hazard materials in air (like potent opioids and other powdered controlled substances), laboratory ventilation guidance and pharmaceutical industry resources prioritizes product containment and isolation through exposure control devices, such as variable air volume chemical hoods, laminar flow ventilated hoods or cabinets, and ventilated gloved boxes [ASHRAE 2015, 2018; Wood 2010].

The results of the 2017 Disposable Glove Use Survey conducted at this workplace and our confidential medical interviews and questionnaires both indicate that availability and use of natural latex rubber gloves were contributing to skin irritation among employees, including some who work in the CSU.

Using natural rubber latex gloves can cause irritation or the development of allergies in some individuals, and the reactions can be mild to severe [NIOSH 1997].

NIOSH does not have specific PPE guidance for forensic chemists but does provide guidance on recommended PPE during investigations and evidence collection. For fentanyl, different levels of PPE are recommended depending on the amount present. At minimal exposure levels, defined by a response where suspected fentanyl may be present but none is visible, nitrile gloves are recommended. At moderate exposure levels, defined by a response where small amounts of fentanyl products are visible, a disposable 100-series filtering facepiece respirator (e.g., P100 filtering facepiece respirator), safety goggles/glasses, and wrist/arm protection are recommended in addition to nitrile gloves [NIOSH 2017]. These two exposure levels are the most similar to employees' exposures during the course of their work. Published guidance from the AAFS and The InterAgency Board provides similar PPE recommendations [AAFS 2017; The InterAgency Board 2017].

Storing used coats in office areas, break areas, on carts, or on the backs of chairs is not ideal and should be discouraged. Providing appropriate used and clean coat storage inside laboratories near exits encourages employees to store their coats in a manner that can reduce surface and hand contamination outside the laboratory.

Limitations

This evaluation is subject to several limitations. Industrial hygiene air and surface sampling can only document potential exposures on the days of sampling in the locations sampled and cannot be taken to represent exposures at other laboratories or exposures on nonsampled days. These results may not be representative of conditions during other days as the casework varies day to day. Because the interviews asked employees about past workplace processes, practices, and conditions; exposures; and health effects, these results are subject to recall bias. Our ability to compare industrial hygiene and biological exposure assessment data to applicable evaluation criteria (such as occupational exposure limits) is limited by the emerging nature of this field and lack of evidence-based evaluation criteria.

Conclusions

An exposure assessment among employees at controlled substances laboratories revealed work-related exposures to controlled substances being handled at work. Cocaine, fentanyl, heroin, and methamphetamine were found in air and wipe samples; and cocaine and its metabolite, fentanyl and its metabolite, and methamphetamine were found in employee urine. No symptoms associated with exposure to cocaine, fentanyl, heroin, or methamphetamine were reported. While the health and safety written programs were thorough, we identified potential factors that contributed to workplace exposures. We provided recommendations to assist the laboratories in minimizing exposures to these substances. These recommendations included improving and enforcing existing workplace practices meant to reduce occupational exposure to controlled substances: changing evidence handling policies, improving access to ventilated workspaces, improving hand hygiene, using PPE consistently, and cleaning laboratory workplaces in accordance with the safety manual.

Section C: Tables

Table C1. End of shift spot urine testing results (n = 18)

Analyte	Range of employee urine concentrations, in ng/mL*	Number of employees' concentrations at or above LOQ† (%)	Laboratory LOQ, in ng/mL	Federal initial drug test cutoff concentrations, in ng/mL
Cocaine‡	NQ§–0.44	9 (50)	0.01	—
Benzoylecgonine	NQ–11	7 (39)	0.05	150
Fentanyl‡	NQ–0.045	1 (6)	0.005	—
Norfentanyl‡	NQ–0.088	1 (6)	0.005	—
Heroin‡	NQ	0 (0)	0.01	—
6-acetylmorphine	NQ	0 (0)	0.05	10
Morphine	NQ	0 (0)	2	2000
Hydromorphone	NQ	0 (0)	5	300
Methamphetamine	NQ–5.8	12 (67)	0.005	500

* Nanograms of analyte per milliliter of urine.

† Limit of quantification

‡ Federal workplace drug testing cutoff concentrations for these analytes have not been established.

§ NQ = Not quantifiable; urine concentrations below the laboratory LOQ values are reported as NQ.

Table C2. Estimated half-life and urine detection window of analytes included in urine testing

Analyte	Urine half-life	Urine detection window
Cocaine	45–90 minutes*†	45 minutes‡
Benzoylecgonine	7.5 hours†	2–5 days†§
Fentanyl	3–12 hours†‡	1–4 days†‡
Norfentanyl¶	—	3–4 days‡
Heroin**	2–6 minutes†‡	—
6-acetylmorphine	30 minutes†	2 hours–1 day†§
Morphine	2–3 hours*†	1–3 days†§
Hydromorphone	1.5–3.8 hours†	2–4 days†§
Methamphetamine	8–17 hours*†	1–2 days†§

* Bateman et al. 2014

† Swotinsky 2015

‡ Baselt 2008

§ Dasgupta 2017

¶ Estimates of urine half-life of norfentanyl are not available.

** Estimates of urine detection windows for heroin are not available because heroin is essentially completely metabolized into the listed metabolites and not excreted as heroin in the urine.

Table C3. Full-shift personal air sample concentrations, in micrograms per cubic meter ($\mu g/m^3$)*

	Cocaine	Fentanyl	Heroin	Methamphetamine
Geometric Mean	0.010	0.003	0.007	0.026
Minimum	NQ	NQ	NQ	NQ
Maximum	0.073	0.010	0.10	0.23

NQ = Not quantifiable; concentration is below the minimum reportable concentration at which the laboratory can accurately quantify results.

* The minimum reportable concentrations range from 0.004 to 0.005 $\mu g/m^3$.

Table C4. Individual full-shift personal air sample concentrations (µg/m^3)*

Participant	Sample duration (minutes)	Cocaine	Fentanyl	Heroin	Methamphetamine	MQC
1*	482	0.0079	NQ	NQ	0.091	0.004
2*	500	0.0063	NQ	NQ	0.026	0.004
3*	475	NQ	NQ	NQ	0.047	0.004
4	472	0.0050	NQ	NQ	0.043	0.004
5	481	0.013	NQ	0.063	0.0044	0.004
6*	479	0.073	0.01	0.047	NQ	0.004
7	343	0.012	NQ	0.018	0.0049	0.004
8*	251	0.010	NQ	0.0081	NQ	0.004
9	404	0.042	NQ	NQ	0.23	0.005
10	472	0.038	NQ	0.0075	0.21	0.004
11	435	0.013	NQ	0.10	0.067	0.005
12	476	0.0065	NQ	NQ	0.016	0.004
13	404	0.016	NQ	0.0062	0.068	0.005
14	216	0.014	NQ	NQ	0.083	0.005
15	458	0.0042	NQ	NQ	0.016	0.004
16	430	0.012	0.0051	0.0080	0.065	0.005
17	421	NQ	NQ	NQ	NQ	0.005
18	463	NQ	NQ	NQ	0.024	0.004

MQC = Minimum quantifiable concentration

NQ = Not quantifiable; concentration is below the minimum reportable concentration at which the laboratory can accurately quantify results.

* Indicates that one of the samples collected on this individual was longer than the recommended sample time (120 minutes).

Table C5. Individual preshift and postshift handwipe samples (ng/wipe)*

Participant	Cocaine		Fentanyl		Heroin		Methamphetamine	
	Preshift	Postshift	Preshift	Postshift	Preshift	Postshift	Preshift	Postshift
1	3.6	150	NQ	5.1	NQ	51	6.8	380
2	5.7	41	NQ	NQ	NQ	5.9	14	40
3	NQ	4.2	NQ	NQ	NQ	12	NQ	250
4	NQ	27	NQ	3.1	NQ	18	NQ	27
5	NQ	250	NQ	17	NQ	150	NQ	30
6	NQ	75	NQ	7.3	NQ	440	NQ	6.8
7	NQ	67	NQ	3.0	NQ	5.7	NQ	3.7
8	3.5	71	1.2	11	NQ	610	1.6	3.2
9	NQ	1500	NQ	440	NQ	3.7	3.9	24
10	NQ	79	NQ	NQ	NQ	24	NQ	75
11	1.8	30	NQ	NQ	NQ	16	1.9	42
12	13	200	NQ	1.6	NQ	40	1.7	52
13	NQ	480	NQ	14	NQ	38	1.6	660
14	9.3	770	NQ	750	NQ	8.1	6.6	190
15	6.1	79	NQ	40	1.0	54	1.4	70
16	24	400	NQ	29	NQ	62	20	300
17	1.1	4.6	NQ	NQ	NQ	NQ	NQ	1.3
18	NQ	52	NQ	1.1	2.4	9.4	NQ	11

NQ = Not quantifiable; concentration is below the minimum reportable concentration at which the laboratory can accurately quantify results.

Table C6. Surface sample results (µg per 100 cm²)*

Laboratory	Location	Fentanyl	Heroin	Methamphetamine	Cocaine
B	Balance	0.048	0.43	0.055	1.8
A	Inside laboratory hood	0.055	0.057	0.12	0.004
A	Inside laboratory hood	0.022	0.052	0.79	0.21
B	Inside laboratory hood	0.37	0.072	0.012	0.24
B	Instrument keyboard	0.015	0.16	0.054	0.80
B	Keyboard in laboratory	0.47	3.4	0.059	2.4
B	Keyboard in laboratory	0.13	0.56	0.063	2.4
D	Keyboard in laboratory	0.24	0.79	0.93	4.2
D	Keyboard in laboratory	0.011	0.026	0.23	2.1
A	Keyboard in laboratory	0.0053	0.15	1.4	1.8
C	Keyboard in laboratory, glove	0.041	0.64	8.6	5.5
C	Keyboard in laboratory, no glove	0.0046	0.15	0.65	1.6
C	Lab bench surface	0.0025	0.043	0.32	0.63
A	Lab bench surface	0.055	0.51	3.7	3.5
A	Lab bench surface	0.035	1.9	0.41	0.41
A	Lab bench surface	0.0091	0.39	0.75	3.3
A	Lab bench surface	0.0084	0.0022	0.0088	0.075
A	Lab bench surface	0.0083	NQ	0.28	0.14
A	Lab bench surface	0.0015	0.011	0.013	0.040
B	Lab bench surface	0.42	0.71	0.041	5.6
B	Lab bench surface	0.39	0.62	0.68	2.0
B	Lab bench surface	0.16	0.20	0.013	0.19
B	Lab bench surface	0.089	0.027	0.015	0.23
B	Lab bench surface	0.033	0.075	0.024	0.74
B	Lab bench surface	0.013	0.073	0.037	0.21
B	Lab bench surface	0.0063	0.010	0.015	0.81
C	Lab bench surface	0.21	0.23	3.7	2.6
C	Lab bench surface	0.015	0.13	0.034	6.6
C	Lab bench surface	0.0059	0.067	0.28	0.038
C	Lab bench surface	0.0025	0.025	0.25	0.97
C	Lab bench surface	0.0020	0.0046	2.1	0.087
C	Lab bench surface	NQ	NQ	0.43	1.6
D	Lab bench surface	0.028	0.12	0.24	2.5
D	Lab bench surface	0.015	0.059	0.17	0.37
D	Lab bench surface	0.012	0.0059	0.24	0.27
D	Lab bench surface	0.008	0.19	0.77	0.75
D	Lab bench surface	0.0037	0.024	1.5	0.44
A	Lab bench surface, near instrument	0.0035	1.4	59	3.8
B	Lab bench surface, near instrument	0.012	0.0015	0.52	0.81
A	Report area	NQ	NQ	NQ	0.0032
B	Report area	NQ	0.0013	0.0011	0.010
C	Report area	NQ	0.0025	0.047	0.053
C	Report area	NQ	0.0021	0.029	0.13
A	Report area	NQ	0.0021	0.010	0.023
D	Report area	NQ	0.0050	0.010	0.018
D	Report area	NQ	0.0051	NQ	0.0041

NQ = Not quantifiable; concentration is below the minimum reportable concentration at which the laboratory can accurately quantify results.
*Keyboard sample area was approximately 100 cm².

Table C7. Frequency of PPE use and hygiene practices in the 2 weeks preceding our return visit, reported by employees completing a questionnaire (n = 19)

Practice	Frequency		
	Always	Sometimes	Never
Wear laboratory coat	15	3	1
Wear nitrile gloves	13	5	1
Wear eye protection	7	11	1
Wear respirator	0	6	13
Wash hands before eating/drinking/smoking	15	3	1
Wash hands before leaving laboratory	8	10	1
Eat/drink/store food or drink in laboratory	0	4	15

Table C8. Description of training activities reported by employees completing a questionnaire

Training	Number of employees (n = 19)
Naloxone use	19
Respirator donning and doffing	19
PPE requirements for handling unknown powders	18
Recognition of opioid intoxication	17
Respirator maintenance and care	17

Table C9. Summary from selected literature – health effects of severe cocaine, fentanyl, heroin, and methamphetamine toxicity*

Controlled substance	Health effects
Cocaine	Dilated pupils, sweating, agitation, anxiety, elevated heart rate and blood pressure, heart arrhythmias, stroke, seizures, and high body temperature
Fentanyl	Lethargy or other indications of central nervous system depression, shallow or slow breathing, miosis or pinpoint pupils, slow heart rate, low blood pressure, low body temperature
Heroin	Lethargy or other indications of central nervous system depression, shallow or slow breathing, miosis or pinpoint pupils, slow heart rate, low blood pressure, low body temperature
Methamphetamine	Dilated pupils, sweating, agitation, anxiety, hallucinations, elevated heart rate and blood pressure, heart arrhythmias, stroke, seizures, high body temperatures, and electrolyte abnormalities (e.g., low potassium or sodium or elevated blood glucose)

* Bateman et al. 2014

Section D: References

Cleaning and Decontamination

Reitstetter R, Losser T [2018]. The synthetic opioid fentanyl is degraded by temperature and ultraviolet irradiation in the environment, https://www.epa.gov/sites/production/files/2018-11/documents/decon_poster_099.pdf.

Sisco E, Najarro M, Burns A [2019a]. Quantifying the effectiveness of cleaning agents at removing drugs from laboratory benches and floor tiles. Forensic Chem *12*(3):1–7, https://doi.org/10.1016/j.forc.2018.11.002.

Sisco E, Robinson EL, Burns A, Mead R [2019b]. What's in the bag? Analysis of exterior drug packaging by TD-DART-MS to predict the contents. Forensic Sci Int *304*:109939, https://doi.org/10.1016/j.forsciint.2019.109939.

Health Effects and Toxicology of Illicit Drug Exposure

Bateman DN, Jefferson RD, Thomas SHL, Thompson JP, Vale JA, eds. [2014]. Oxford desk reference: toxicology. 1st ed. New York: Oxford University Press.

Baselt RC [2008]. Disposition of toxic drugs and chemicals in man. 8th ed. Foster City, CA: Biomedical Publications.

Dasgupta Amitava [2017]. Alcohol, drugs, genes and the clinical laboratory: an overview for healthcare and safety professionals. 1st ed. Cambridge, MA: Elsevier, Inc.

Jenkins AJ, Llosa T, Montoya I, Cone EJ [1996]. Identification and quantitation of alkaloids in coca tea. Forensic Sci Int *77*(3):179–189.

Rohrig TP, Moore C [2003]. The determination of morphine in urine and oral fluid following ingestion of poppy seeds. J Anal Toxicol *27*(7):449–452, http://dx.doi.org/10.1093/jat/27.7.449.

Swotinsky RB [2015]. The medical review officer's manual: MROCC's guide to drug testing. 5th ed. Beverly Farms, MA: OEM Health Information, Inc.

Methods

Bureau Veritas North America [2018]. E-mail message from Allen Shinsky (PhD) to Jennifer Roberts (NIOSH), October 26.

Occupational Exposure Limits

Van Nimmen NFJ, Veulemans HAF [2004]. Development and validation of a highly sensitive gas chromatographic-mass spectrometric screening method for the simultaneous determination of nanogram levels of fentanyl, sufentanil and alfentanil in air and surface contamination wipes. J Chromatogr A *1035*(2):249–259, http://dx.doi.org/10.1016/j.chroma.2004.02.074.

Van Nimmen NFJ, Poels KLC, Veulemans HAF [2006]. Identification of exposure pathways for opioid narcotic analgesics in pharmaceutical production workers. Ann Occup Hyg *50*(7):665–667, http://dx.doi.org/10.1093/annhyg/mel028.

Other

EPA [2018]. Fact sheet for OSCs: fentanyl and fentanyl analogs. Washington, DC: U.S. Environmental Protection Agency, https://www.epa.gov/sites/production/files/2018-07/documents/fentanyl_fact_sheet_ver_7-26-18.pdf.

NIOSH [1997]. Preventing allergic reactions to natural rubber latex in the workplace. 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. 1997-135, http://www.cdc.gov/niosh/docs/97-135/.

NIOSH [2011]. Evaluation of police officers' exposures to chemicals while working inside a drug vault – Kentucky. By Fent KW, Durgam S, West C, Gibbins J, Smith J. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Health Hazard Evaluation Report 2010-0017-3133, https://www.cdc.gov/niosh/hhe/reports/pdfs/2010-0017-3133.pdf.

NIOSH [2017]. Fentanyl: preventing occupational exposure to emergency responders. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, https://www.cdc.gov/niosh/topics/fentanyl/risk.html.

NIOSH [2019]. Evaluation of occupational exposures to illicit drugs at controlled substances laboratories. By Broadwater KR, Jackson DA, Li JF. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Health Hazard Evaluation Report 2018-0090-3366, https://www.cdc.gov/niosh/hhe/reports/pdfs/2018-0090-3366.pdf.

Standards, Guidance, and Recommendations

AAFS [2017]. AAFS position statement. Colorado Springs, CO: American Academy of Forensic Science, https://www.aafs.org/wp-content/uploads/Position_Stmt_Opioid_Safety_Plans.pdf.

American Society of Crime Laboratory Directors [2018]. Opioid safety and handling: best practice recommendations. Garner, NC: ASCLD Opioid Task Force, https://www.ascld.org/wp-content/uploads/2018/05/Opioid-Safety-and-Handling.pdf.

ANSI/AIHA [2012]. ANSI/AIHA Z9.5-2012 Laboratory ventilation. American National Standards Institute/American Industrial Hygiene Association. Falls Church, VA: American Industrial Hygiene Association.

ASHRAE [2015]. Laboratory design guide: planning and operation of laboratory HVAC systems. Atlanta, GA: ASHRAE, https://www.ashrae.org/.

ASHRAE [2018]. Classification of laboratory ventilation design levels. Atlanta, GA: ASHRAE, https://www.ashrae.org/.

California Legislature [2019]. Assembly Bill 1596 Hazardous substances: contaminated property: fentanyl cleanup, https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201920200AB1596.

Colorado Department of Public Health and Environment [2005]. Support for selection of a cleanup level for methamphetamine at clandestine drug laboratories. Denver, CO: Colorado Department of Public Health and Environment, https://www.colorado.gov/pacific/sites/default/files/HM_clean-up-level-support.pdf.

DHHS [2017]. Substance Abuse and Mental Health Services Administration. Revised Mandatory Guidelines by the Secretary of Health and Human Services. Notice 82 FR 7920. Document Number 2017-00979, https://www.federalregister.gov/documents/2017/01/23/2017-00979/mandatory-guidelines-for-federal-workplace-drug-testing-programs.

EPA [2013]. Voluntary guidelines for methamphetamine laboratory cleanup. Washington, DC: U.S. Environmental Protection Agency, https://www.epa.gov/emergency-response/voluntary-guidelines-methamphetamine-laboratory-cleanup-document.

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

The InterAgency Board [2017]. Recommendations on selection and use of personal protective equipment and decontamination products for first responders against exposure hazards to synthetic opioids, including fentanyl and fentanyl analogues. Arlington, VA: The InterAgency Board, https://www.interagencyboard.org/sites/default/files/publications/IAB%20First%20Responder%20PPE%20and%20Decontamination%20Recommendations%20for%20Fentanyl.pdf.

Wood J, ed. [2010]. Containment in the pharmaceutical industry. Vol 108. New York: CRC Press.

Delivering on the Nation's promise: Promoting productive workplaces through safety and health research

Get More Information

Find NIOSH products and get answers to workplace safety and health questions:

1-800-CDC-INFO (1-800-232-4636) | TTY: 1-888-232-6348
CDC/NIOSH INFO: cdc.gov/info | cdc.gov/niosh
Monthly *NIOSH eNews*: cdc.gov/niosh/eNews