Evaluation of Forensic Crime Lab Employees' Chemical Exposures, Job Stress, and Work-Related Health Concerns

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Contents

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

Highlights of this Evaluation

The National Institute for Occupational Safety and Health (NIOSH) received a request from The Health Hazard Evaluation Program received a request from an employer representative at a federal crime lab who was concerned about lab employees' potential chemical exposures. As part of our evaluation, we also asked employees about psychosocial and work organization factors at work. We visited the lab three times: November 2012, February 2014, and March 2015.

What We Did

- We developed a system to select procedures in case working units for evaluation. We selected procedures in the nuclear and mitochondrial deoxyribonucleic acid, firearms and toolmarks, latent prints operations, and operational projects units.
- We sampled the workplace air for lead, ethyl cyanoacrylate, methanol, methylene chloride, and particles.
- We observed the use of formamide.
- We evaluated ventilation in the firing range and at the wet bullet trap.
- We talked to employees about job stress and work-related health concerns.

What We Found

- Employees were not overexposed to airborne hazards.
- Some employees may be exposed to methylene chloride through the skin. Protective gloves were not always used.
- The canopy exhaust hood in the wet bullet tank room was ineffective in capturing firearm emissions in the breathing zone of the shooter.
- On average, employees reported moderate job stress. They reported strict deadlines, high workload, and lack of resources.
- On average, employees reported a low level of concern about their work-related health.
- Employees reported that inadequate communication and a high workload were problems.

We developed a system to prioritize risks from chemical exposures across case working units and evaluate potential health hazards in a forensic lab. In general, exposures were well controlled. We found some employees could have dermal exposure to methylene chloride. We also found an exhaust hood not operating properly. Employees expressed moderate job stress and low concern about work-related health. We recommended that the employer require employees to wear gloves when handling methylene chloride, evaluate the hood, and talk to employees about managing their workload.

What the Employer Can Do

- Use the system we developed to set priorities for evaluating exposures in other work units.
- Provide employees gloves for handling methylene chloride.
- Evaluate the local exhaust ventilation of the wet bullet trap.
- Talk to employees about managing workload.
- Use the annual Federal Employee Viewpoint Survey results to identify communication concerns.
- Encourage employees to use wellness and stress reduction services, such as LifeCare (http://www.lifecare.com).

What Employees Can Do

- Wear gloves when handling methylene chloride.
- Use wellness and stress reduction services, such as LifeCare (http://www.lifecare.com).

Abbreviations

$\mu g/m^3$	Micrograms per meter cubed
ACGIH®	American Conference of Governmental Industrial Hygienists
BLL	Blood lead level
CFR	Code of Federal Regulations
dB	Decibel
DFO	1,8-diazafluoren-9-one
DNA	Deoxyribonucleic acid
FBI	Federal Bureau of Investigation
GHS	Globally Harmonized System of Classification and Labelling of Chemicals
HEPA	High-efficiency particulate arrestance
mg/m^3	Milligrams per meter cubed
mL	Milliliter
NIN	Ninhydrin
NIOSH	National Institute for Occupational Safety and Health
OEB	Occupational exposure band
OEL	Occupational exposure limit
OSHA	Occupational Safety and Health Administration
PCR	Polymerase chain reaction
PEL	Permissible exposure limit
PPE	Personal protective equipment
ppm	Parts per million
RAM	Rhodamine
REL	Recommended exposure limit
STEL	Short-term exposure limit
TLV®	Threshold limit value
TWA	Time-weighted average
WEEL™	Workplace environmental exposure level

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Introduction

The Health Hazard Evaluation Program received a request from the health and safety director at a Federal Bureau of Investigation (FBI) crime laboratory (lab) to evaluate workplace health hazards. Approximately 800 employees worked in the lab across the following 13 "case working units (unit):"

- Trace evidence
- Chemistry
- Nuclear and Mitochondrial deoxyribonucleic acid (DNA)
- Questioned documents
- Firearms and toolmarks
- Explosives
- Latent print operations
- Operational projects
- Federal DNA database
- Chemical, biological, radiological, and nuclear science
- Scientific response
- Forensic imaging
- Counterterrorism and forensic science research

We visited the lab in November 2012, February 2014, and March 2015. We sent letters summarizing preliminary results and recommendations in January 2013, March 2014, April 2015, and July 2015. We first analyzed procedures and exposure risks across all the units. Then, we used this information to select units for exposure assessment.

Methods

Our objectives were the following:

1. Identify procedures and exposures that presented the greatest potential health risk to employees.
2. Assess employee exposures from these higher risk procedures.
3. Provide recommendations to reduce employees' chemical exposures.
4. Determine job stress and work-related health concerns.

The methods we used to achieve our objectives were to:

1. Survey key individuals in each of the units to identify the procedures they believe involve the greatest risk in terms of toxicity and frequency of chemical exposure.
2. Use the survey data to prioritize the 25 procedures of greatest health risk.
3. Use observations of the top 25 procedures along with professional judgement to select 10 procedures for personal exposure monitoring.
4. Assess employees' perceptions of job stress and other work-related health concerns.

Selecting Case Working Units for Evaluation

During our visit in November 2012, we conducted a walk through survey of the lab. We obtained the standard operating procedures for all crime lab procedures and used this information to develop a chemical hazard survey (Appendix C). In May 2013, we mailed the survey to the health and safety director for dissemination to two to three employees in each unit who were familiar with the span of work in their assigned unit. The completed surveys were mailed back to us, and then we analyzed the survey results using the following three-step process.

Step one: We entered the work procedures and chemicals for each unit into a spreadsheet. We listed every chemical used in each of the procedures in a separate cell and evaluated each chemical individually.

Step two: We ranked work procedures from 1 (lowest) to 5 (highest) on the basis of the following elements.

- The *frequency* of the procedure.
- The likelihood for employee *exposure*, considering engineering controls.
- The *number* of potentially exposed employees.
- The occupational exposure limit *(OEL)* or occupational exposure band *(OEB)*.

For example, a value of 1 for each variable would indicate the procedure was infrequently done, employees had a low potential for exposure, the number of potentially exposed employees was small, and the chemicals used had a higher OEL or OEB. A value of 5 for each variable would indicate the procedure was frequently done, employees had a high potential for exposure, the number of employees potentially exposed was large, and the chemicals had low OELs or OEBs. Occupational exposure banding is a technique used to evaluate chemicals on the basis of toxicological properties; we describe it in Appendix D. We include a description of the numerical values assigned for each variable in Appendix E.

Step 3: We calculated a total rank score for the procedure by adding up the numerical rankings for each variable using the following equation.

$$Frequency_{RANK}+Exposure_{RANK}+Number_{RANK}+OEL_{RANK}=Total_{RANK}$$

The lowest possible total rank score was 4 and the highest was 20. We used this score to prioritize and select the procedures we would observe and evaluate during our second site visit. Appendix F lists the highest ranked procedures. We added three procedures in the firearms and tool marks unit to our list because of potential lead exposure, because lead was of particular interest to the investigators.

During our February 2014 visit, we observed work practices among employees doing the selected procedures, documented the volume of chemicals used and exposure duration, and identified engineering and administrative controls and personal protective equipment (PPE).

We used this information along with input from the lab's health and safety director to select the following 10 procedures to evaluate during our March 2015 visit (Table 1). We selected chemicals used or generated during procedures for monitoring based their toxicity, quantity used, vapor pressure, and availability of sampling and analytical methods.

Table 1. Procedures selected for exposure assessments

Case working unit	Procedure
Mitochondrial and nuclear DNA	Filling trays with formamide Pipetting formamide from tray
Firearms and toolmarks	Testing firearms Examining and comparing bullets for markings Examining gunshot residue
Latent print operations	Dusting for fingerprints Fingerprint analysis using NIN, RAM, and DFO Superglue fuming for fingerprints
Operational projects	Transferring methylene chloride into a secondary container Using methylene chloride to connect two plastic parts

DFO = 1,8-diazafluoren-9-one

NIN = Ninhydrin

RAM = Rhodamine

Chemical Exposure Assessment

We observed employees using formamide in the mitochondrial and nuclear DNA units.

In the firearms and toolmarks unit, we collected 26 surface wipe samples for lead using SKC Inc. Full Disclosure® wipes. Where possible, we used a 10 centimeter by 10 centimeter template to outline the sample area. For small or irregularly shaped surfaces such as doorknobs we estimated 100 square centimeters or took a sample of the entire area or object. We wore a new pair of nitrile gloves to take each sample. In addition to visually assessing the wipes, which have an estimated visual limit of detection of 19 micrograms of lead per wipe, we sent them for laboratory analysis using National Institute for Occupational Safety and Health (NIOSH) Method 9102 [NIOSH 2016].

We used a smoke machine to observe airflow patterns inside the firing range and evaluate pressurization of the range relative to other areas of the lab. We tested the ventilation system in the range and wet bullet trap using a TSI VelociCalc® Plus Model 8386A anemometer and compared the measurements to published NIOSH guidelines [NIOSH 2009]. We also used a TSI® Inc. condensation particle counter direct reading instrument to evaluate the ventilation system in the wet bullet trap while discharging firearms into the ballistics tank.

In the latent print operations unit, we measured airborne total dust levels using an ART® Instruments optical particle counter and a DustTrak® DRX aerosol monitor while forensic examiners were dusting for fingerprints. We used smoke tubes to visually evaluate the downdraft table used by employees dusting for prints, and an anemometer to measure airflow at the chemical fume hoods used for fingerprint analysis. We also collected and analyzed personal and area air samples from 13 examiners over 2 days for methanol using NIOSH Method 2000 [NIOSH 2015]. We selected methanol as an indicator of exposure to NIN, RAM, and DFO because these chemicals are mixed with methanol but do not have OELs. We collected area air samples inside and outside of the fume hoods. While employees were using superglue for fingerprint analysis, we collected and analyzed air samples for ethyl cyanoacrylate according to the Occupational Safety and Health Administration (OSHA) Method 55 [OSHA 2016]. We collected area and personal air samples over 2 days. All area air samples were collected outside of the superglue fuming chamber.

We measured exposures to methylene chloride using Dräger® direct-reading colorimetric tubes. We sampled when employees in the operational projects unit poured methylene chloride into a secondary container in the paint spray booth and when they used methylene chloride to connect pieces of plastic in the shop.

Employee Interviews

We used a semistructured interview form to complete confidential medical interviews with a convenience sample of employees during our February 2014 visit. Of the 800 employees in the building, approximately 144 worked in the units of interest. Many of these employees were not available for interviews because they were in the field or on leave. The interview focused on perceptions of job stress, psychosocial factors at work, and other work-related health concerns.

We asked participants to rate their level of job stress with the following question: "During the past week, including today, how would you rate your current job stress level on a scale from 0 (as low as it can be) to 10 (as high as it can be)?" Responses of 0–3 indicated low job stress, 4–6 indicated moderate job stress, and scores of 7 or greater indicated high job stress [Clark et al. 2011]. We also asked an open-ended question about what factors contribute to perceptions of job stress.

We read a list of nine general psychosocial factors to employees, asking whether they perceived each to be "a problem in general at your place of work" (yes/no responses with the interviewer probing further on identified problem areas).

We asked participants to rate their level of work-related health concern with the following question: "On a scale from 0 (not at all concerned) to 10 (very much concerned) how concerned are you about your health as a result of your current occupation? Responses of 0–3 indicated low concern, 4–6 indicated moderate concern, and scores of 7 or greater indicated high concern [Clark et al. 2011]. Finally, we asked an open-ended question about having health problems employees believed were work-related.

Results and Discussion

Using unit leaders' responses to the survey of chemical hazards, we identified 25 procedures that could present a higher risk to employees than the other procedures (Appendix F). Because the survey relied on employee judgement, the risks may be misclassified. The results reflect the knowledge and opinions of the respondents, which can vary. For example, after reviewing the final rankings, we identified three procedures in the firearms and toolmarks unit that could expose employees to lead, but these procedures had not been ranked in the top 25, mainly because their frequency and number rankings were low. Because lead has a low OEL (NIOSH REL = 0.05 mg/m^3) and exposures should be tightly controlled, we included these three procedures in the final 10 procedures where we did in-depth exposure monitoring.

The 10 procedures we evaluated do not necessarily represent those of highest risk because various factors played into our selection process, including availability of analytical methods. We also ranked three tasks involving iodine as "higher risk;" however, we did not evaluate them because of how infrequently employees performed them (less than once a year). Also, several chemicals used in high ranking procedures did not have OELs or reputable toxicological data on which to base the OEB. We provided the complete rank-ordered list of procedures (109 total) to the lab's health and safety director for use in prioritizing future sampling or planning control measures.

The work at this facility involved a large number of tasks and chemicals. Many of these chemicals were used infrequently, were known or suspected to be present in small quantities, and often were used with local exhaust ventilation. Our prioritization strategy helped to narrow the focus of the assessment to those tasks with higher risk relative to other tasks. The prioritization strategy developed here may be useful in future evaluations of crime labs or other facilities where a large number of procedures, involving a large number of chemicals, are done.

Nuclear and Mitochondrial DNA Units

These two units examined evidence using serological, mitochondrial DNA, and nuclear DNA methodologies. DNA units analyzed evidence including body fluid stains or other biological tissues, as well as hair, bone, or teeth fragments. Potential chemical exposures included phenol, pyridine, chloroform, isoamyl alcohol, and formamide. The lab employees typically handled chemicals in a three-sided, non-ventilated enclosure (Figure 1), but some tasks using formamide occurred on the open benchtop. PPE included surgical masks (worn to protect the evidence), nitrile gloves, cloth lab coats, and safety glasses with side shields.

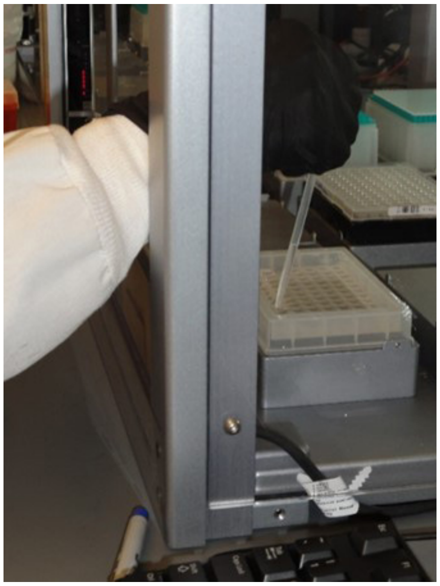

Figure 1. A DNA unit employee pipetting formamide inside of a three-sided, non-ventilated enclosure. Photo by NIOSH.

On the basis of our initial observations and professional judgment, we determined that typical use of formamide would not likely result in exposures above the American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV) of 10 parts per million (ppm). We considered that because of its vapor pressure (0.08 millimeters of mercury at room temperature), formamide is unlikely to evaporate quickly. In addition, small quantities (about 20 milliliters [mL] per day) are used. We determined that the likeliest employee exposure would be dermally from a spill and subsequent cleanup.

We observed two tasks that could result in dermal exposure to formamide through spills. The first task involved carrying 20 mL of formamide from its storage location to the polymerase chain reaction (PCR) workstation. The second task, done on an open benchtop, involved pouring 20 mL of formamide into a container and then pipetting 20 microliters of formamide into the wells of a PCR tray. Employees had a spill cleanup procedure which included donning additional protective clothing such as safety goggles, placing a barrier around the spill, using Chemwipes® to absorb the spilled formamide, then disposing of the wipes in the hazardous waste container.

Firearms and Toolmarks Unit

The firearms and toolmarks unit employees examined evidence related to firearms, ammunition, tools, and toolmarks (the physical characteristics left by objects found at a crime scene). Employees examined bullet and cartridge case characteristics, gunshot residue, and shot patterns and did firearm functionality testing. They compared tools to toolmarks, examined locks and keys, and restored serial numbers for stolen vehicles, heavy equipment, and firearms. Some employees also reconstructed shooting incidents and performed bullet hole and impact analyses at the crime scene. Employees wore cloth lab coats, nitrile gloves, and safety glasses when they mixed or used chemicals. They mixed all chemicals inside a

Fisher Hamilton® chemical fume hood.

Investigators discharged all firearms in a two-lane firing range or a wet bullet tank (Figure 2). While shooting, employees wore Moldex Spark Plugs® ear plugs with a noise reduction rating of 33 decibels (dB) or Radians® earmuffs with a noise reduction rating of 20 dB or more. They were not required to wear double hearing protection. Recent NIOSH research on hearing protectors for impulse noise exposures has shown that the combination of ear plugs and muffs can attenuate noise levels by 36–49 dB, if properly fitted and worn [Murphy et al. 2012; NIOSH 2013]. They also wore safety glasses with side shields. Employees had pre-employment audiograms; repeat audiograms were not required but were available on request. The lab previously tested employees' blood for lead but discontinued the program following several years of nondetectable blood lead level (BLLs) results.

Figure 2. Wet bullet tank. Photo by NIOSH.

Figure 3. Firing range. Photo by NIOSH.

Using the Full Disclosure kit, we detected lead on surfaces in the unit (Table 2). We did not detect lead in areas where employees ate or drank, such as their office workstations and the conference room, or where they examined firearms without gloves, such as computer workstations in the ballistics examination area. The cart used to transport firearms from the range to the ballistics examination area tested positive for lead, and employees touched this cart with ungloved hands. Except for the cart, all positive samples for lead were from inside the firing range, inside the wet ballistics tank room, or in the air handling unit for the firing ranges. A positive sample result on the canopy exhaust hood suggests that lead dust could settle on the hood and subsequently become airborne and expose employees when weapons were fired.

Table 2. Surface wipe samples for lead, firearms and toolmarks unit, April 2015

Location	Full disclosure result
In ballistics examination area	
Employee 1 workstation in front of computer	Negative*
Employee 2 workstation in front of computer	Negative
Doorknob to analytical lab	Negative
Floor of ballistics lab	Negative
Mousepad of employee 3 workstation	Negative
Employee 4 workstation, in front of computer	Negative
Doorknob to ballistics lab	Negative
Employee 5 workstation by laptop computer	Negative
Cart used to transport firearms from range	Positive
Employee 6 workstation in front of keyboard	Negative
In firing range	
Inside wet ballistics tank, in front of sink	Negative
Just outside of range, on hallway handrail	Negative
Doorknob to offices from the firing range	Negative
Doorknob inside of the firing range	Negative
Floor just inside the firing range	Positive
Reference ammunition file room workstation	Negative
Reference ammunition file room, doorknob	Negative
On canopy hood over wet ballistics tank	Positive
On lip of ballistics water tank	Negative
On hearing protection stored in range	Positive
Air handling unit	
On prefilter	Positive
On main filter	Positive
On duct tape on outside of fan housing	Positive
Horizontal surface, 10 feet from exhaust	Negative
Office area	
Employee workstation	Negative
Conference room table	Negative

*Below the limit of detection of 19 μg/sample

We submitted the surface wipe samples for quantification, but a laboratory error destroyed the samples during analysis.

The firing range was approximately 5.5 feet wide and 80 feet long (from firing line to bullet trap). It only had one entry and exit point, which consisted of two doors in series. Sticky floor mats were placed at the exit to remove lead contamination from the soles of employees' shoes. Supply air was provided to the firing range from a perforated wall plenum (approximately 5.5 feet wide and 10.5 feet high); air was exhausted at the bullet trap (Figure 3). This air handling system was dedicated to the range and wet ballistics tank only and all of the range air was exhausted out of the building. The air handling unit contained a rotating belt-style prefilter followed by a high-efficiency particulate arrestance (HEPA) filter. The prefilter is changed whenever the filter material from the unused roll has transferred onto the used roll. The HEPA filter has been changed three times in the 11 years that the crime lab has occupied the building. The lab contracted a specialized lead abatement company to perform that work and to advise on when to next replace the HEPA filters.

Investigators fired weapons at any point from the firing line to within 2 feet of the bullet trap, and from any height. We collected three air velocity measurements from floor to ceiling along two firing lines. Although material was stored in front of the air supply plenum, airflow at the first firing line (about 14 feet from the plenum) was relatively evenly distributed from floor to ceiling. It ranged from 122 to 147 feet per minute (Table 3), and exceeded the recommended minimum average air velocity of 50 feet per minute [NIOSH 2009]. We saw no evidence of turbulent air. Airflow downrange also was evenly distributed from floor to ceiling and exceeded the NIOSH recommended minimum air velocity of 30 feet per minute [NIOSH 2009]. Using ventilation smoke we saw no areas of stagnant air, and air traveled consistently from the air supply plenum to the bullet trap without any areas of backflow. See Figure A2 in Appendix A for a drawing of the firing range.

Table 3. Airflow velocity measurements, in feet per minute

Location	Average velocity, floor to ceiling, wall to wall (6 measurements total)	Range
At firing line	133	122 to 147
At midrange	96	88 to 104
At ¾ range	94	81 to 104
At bullet trap	87	86 to 98

The range was under slight negative pressure, meaning that air flowed into the range from adjacent areas. This is desirable so that no airborne contaminants migrate from the range.

The wet bullet trap tank (Figure 4) was in an 18 × 12 foot room adjacent to the firing range. Exhaust ventilation for the trap tank and a canopy hood above where weapons were test fired were connected to the firing range ventilation system (Figure 5). We approximated the breathing zone of the shooter to be 3 feet from the pistol port of the tank and 3 feet below the canopy hood. The average face velocity at the canopy hood was 160 feet per minute; however, at the breathing zone of the shooter the average airflow velocity was 25 feet per minute. Using theatrical smoke we observed that smoke at the pistol port was drawn into the tank, but smoke at the breathing zone of the shooter was not captured by either the canopy hood or tank. Because of the position of the overhead canopy hood in relation to the pistol port, lead fume from the discharged firearm could be drawn back into the breathing zone of the shooter.

Figure 4. Wet bullet trap tank. Photo by NIOSH.

Figure 5. Canopy hood located approximately 3.75 feet above the breathing zone of the firearms inspector. Photo by NIOSH.

Two firearms were discharged into the wet bullet tank, each twice. The first was a Glock® semiautomatic pistol firing .357 Sig rounds with a copper jacket. Upon discharge of the weapon, the particle count rose from approximately 1,000 particles per cubic centimeter to approximately 550,000 particles per cubic centimeter. The second weapon was a Colt® .38 special revolver with a lead wad cutter bullet. After discharging, the particle count increased to approximately 300,000 particles per cubic centimeter. A graph of these results is in Appendix A, Figure A3. We suspect that the concussive force of the first shot dislodged built up dust from the top of the canopy hood because the particle count continued to decrease over time, and we were unable to replicate the 300,000 particle per cubic centimeter spike that occurred with the first shot. The employees indicated that the top of the canopy hood was not cleaned routinely.

Latent Print Operations Unit

The latent print operations unit examined evidence for fingerprints, palm prints, and footprints. Investigators inspected evidence under multiple light sources including visible and ultraviolet light. Depending on the type of evidence the employees performed a series of treatments using chemical reactions to lift ridge detail from the latent prints. After each of the chemical reactions, the employees examined the evidence under the light again. In some instances, employees placed evidence inside a cyanoacrylate (superglue) fuming chamber (Figure 6). They also dusted evidence for fingerprints using magnetic powders (Figure 7). The PPE used by employees included nitrile gloves, cloth lab coats, and goggles.

Figure 6. Superglue fuming chamber. Photo by NIOSH.

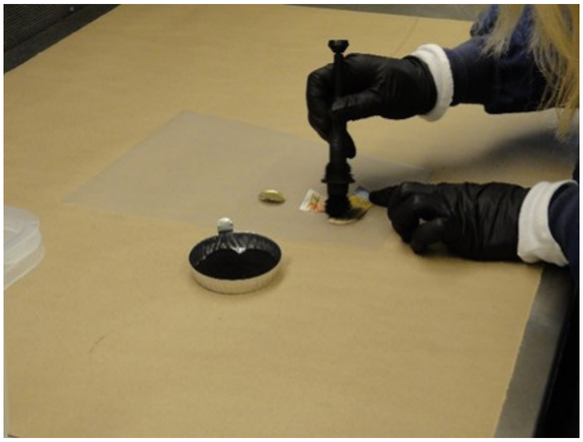

Figure 7. Using carbon black to dust for fingerprints. Photo by NIOSH.

We used smoke tubes to visualize the effectiveness of the exhaust plenum to the rear of the fingerprint dusting table. When we held the optical particle counter near employees while they dusted evidence the particle count spiked. We measured the highest counts for particles in the 0.3 and 0.5 micrometer diameter size range. In addition, when an employee used compressed air to clean the area it produced another smaller spike in particle counts. A graph showing the particle count measurements is in Appendix A, Table A1. Typically, fingerprinting dusts are in the 0.3 micrometer diameter size range and therefore these results could indicate potential for exposure.

Methanol was not detected (minimum detectable concentration was 0.9 ppm) in 15 personal air samples or 5 area air samples collected outside of the fume hoods. We did measure methanol in five area air samples collected inside the fume hoods (concentrations ranged from 1.1–3.7 ppm). The OSHA permissible exposure limit (PEL), NIOSH recommended exposure limit (REL), and the ACGIH® TLV® for methanol are 200 ppm. These results indicate that employees had minimal, if any, exposure, and that the fume hoods kept methanol from escaping. Because NIN, RAM, or DFO have lower vapor pressures than methanol and are not aerosolized, airborne exposure to these chemicals is also unlikely. However, when tasks are carried out on the open benchtop, employee exposure could occur.

No ethyl cyanoacrylate was detected (< 0.025 ppm) in two personal air samples taken on employees performing superglue fuming. These sampling times were 55 minutes and 85 minutes. Likewise, no ethyl cyanoacrylate was detected (< 0.083 ppm) in 15 area air samples collected around the nine superglue fuming chambers. The area air samples were collected from 105 to 254 minutes. These sampling times reflect the time employees typically processed evidenced using superglue fuming during a workday. The ACGIH TLV for ethyl cyanoacrylate is 0.2 ppm for up to a 10-hour time-weighted average (TWA). Our air sampling results indicated that employees are not exposed to ethyl cyanoacrylate during superglue fuming.

Operational Projects Unit

Employees in this unit built crime scene models to display in court hearings. Activities included woodcutting, spray painting, laser cutting of plastics, assembling plastics parts, and 3-dimensional printing. Employees spray-painted and transferred methylene chloride from 1-quart stock containers into 30 mL containers (for use on the shop floor) in a crossdraft ventilation booth (Figure 8). Employees assembled plastic parts using methylene chloride on the shop floor without local exhaust ventilation (Figure 9). The wood shop had a ceiling mounted air handling unit equipped with a HEPA filter, and each saw had local exhaust ventilation. Employees voluntarily wore lab coats, Sperian® N95 filtering facepiece respirators, ear plugs or earmuffs, and nitrile gloves. The lab provided employees with Appendix D of the OSHA respiratory protection standard.

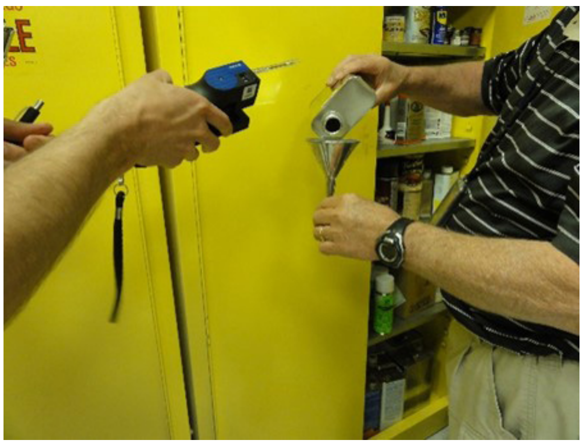

Figure 8. Pouring methylene chloride from 1-quart stock container into 30-mL container. Photo by NIOSH.

Figure 9. Combining plastic parts using methylene chloride. Photo by NIOSH.

We used Dräger direct-reading colorimetric detector tubes to evaluate employee exposures to methylene chloride during the following tasks:

1. Manually transferring methylene chloride from a 1-quart container to a 30-mL squeeze bottle. This task took approximately 2 minutes and was done 1–2 times per month.
2. Hand assembling Plexiglas® parts. A small amount of methylene chloride was squeezed from a 30-mL container (Figure 9) onto the parts. The employee then held the pieces together for a few seconds.

No methylene chloride was detected (< 20 ppm). The employee wore safety glasses but no gloves. The employee reported that when methylene chloride spilled on a surface or on the skin he waited a few minutes for it to evaporate, rather than risk further dermal exposure while cleaning it up. Allowing spilled methylene chloride to evaporate from surfaces is appropriate if the object is inside a chemical fume hood or if the room is well ventilated and unoccupied during the evaporative process. However, skin contact should be prevented by use of chemical protective gloves and if methylene chloride still gets onto skin, it should quickly be washed off because prolonged dermal contact with methylene chloride may produce chemical burns, and it is absorbed slowly through intact skin [ATSDR 2015]."

Employee Interviews

We asked 41 employees to participate in confidential medical interviews, including three or more individuals from each of the following units: firearms and toolmarks, trace evidence, nuclear and mitochondrial DNA, latent print operations, operational projects, federal DNA database, and forensic imaging. One employee refused to participate, resulting in a sample size of 40 employees (28% of employees working in the units of interest). Some employees chose to skip particular questions during the interview.

Job Stress and Psychosocial Factors

The average job stress score among 39 respondents was 5.5, indicating moderate job stress overall. Grouping the individual scores, 9 (23%) employees indicated low job stress, 14 (36%) indicated moderate job stress, and 16 (41%) indicated high job stress. The average level of perceived job stress was the same as that reported among 70 employees during a NIOSH evaluation at another federal law enforcement agency [NIOSH 2014].

We asked employees an open-ended question to identify what they believe contributes to their job stress. Strict deadlines (n = 17), high workload (n = 14), having insufficient resources (n = 8), and interpersonal issues with coworkers or supervisors (n = 7) were the most frequently reported sources of job stress.

We read a list of nine general psychosocial factors to the employees and asked them to indicate whether each was a problem in general at work. Table 4 includes the list of psychosocial factors and the number of participants indicating whether each was a problem at work. The most frequently reported problems were communication, workload or speed, lack of resources, and interpersonal relationships.

Table 4. Employees' perceptions of whether general psychosocial factors were problems at work (N = 40)

Psychosocial factor	Number of participants indicating a need for improvement (%)
Communication issues between employer and employees	32 (80)
Workload or speed	26 (65)
Lack of resources	25 (63)
Interpersonal relationships with coworkers or supervisors	15 (38)
Amount of control over how and when job tasks are performed	7 (18)
Job security	7 (18)
Effectiveness of safety policies and procedures	3 (8)
Scheduling or overtime	3 (8)
Safety climate: the values, attitudes, beliefs, and/or behaviors that pertain to an organization's safety and health program	3 (8)

The two methods we used to identify perceived stressors in the workplace produced similar results, although the forced choice (yes/no) format yielded a higher number of individuals reporting particular stressors than the open-ended format. We identified job demands such as workload and strict timelines as major stressors, along with a lack of resources (most often described as a shortage of staff). NIOSH defines job stress as "the harmful physical and emotional responses that occur when the requirements of a job are a poor match to the capabilities, resources, or needs of the worker" [NIOSH 1999]. The employees reported that while the amount of work had recently increased, the workforce had diminished, which increased individual workload while working with what were already strict deadlines. This scenario may explain some employees' perceptions of moderate to high job stress.

We identified interpersonal conflict at work as another stressor. In the open-ended response format, we described interpersonal conflict as working with others who were perceived as having negative attitudes, having negative interactions with others when competing for resources, and being in disagreement about policies and procedures. Interpersonal conflict at work has been linked to increased turnover and absenteeism; decreased coordination and collaboration; lower efficiency and productivity at the organizational level; and burnout, frustration, and decreased well-being at the personal level [De Dreu et al. 2007].

Work-related Health Concerns

On a scale of 0 (as low as it can be) to 10 (as high as it can be), the average work-related health concern score was 3.0 (N = 40). Based on individual scores, 24 (60%) employees indicated low concern, 11 (28%) indicated moderate concern, and 5 (13%) indicated high concern.

We asked employees if they had any health symptoms they believed were work related. One third of interviewed employees reported no health symptoms they believed were work related. The most frequently reported work-related health symptoms were allergies attributed to indoor environmental quality (n = 7) and job stress in general (n = 7). Some employees reported other symptoms that are associated with job stress, such as musculoskeletal pain, anxiety, and fatigue or sleep disturbances.

In a review of the relationships between job stressors and physical symptoms, Nixon et al. [2011] found that interpersonal conflict, diminished resources, and workload were significantly related to musculoskeletal symptoms, sleep disturbances, fatigue, dizziness, loss of appetite, and gastrointestinal problems.

On average, employees reported a low level of concern about their work-related health. However, if employees continue to experience moderate to high job stress, the prevalence of some symptoms may increase over time.

The results of the 40 employee interviews may not apply to all 144 employees in the units of interest. The number of employees interviewed was small (28% of the population) and we did not randomly select the employees to interview.

Conclusions

The method we used to review, prioritize, and select units for evaluation is applicable to other occupational environments. Our personal sampling results showed that employees were not overexposed to airborne chemicals used in the units. However, we observed opportunities for dermal exposure to some chemicals because employees did not always use protective gloves. The firing range in the firearms and toolmarks unit performed in accordance with NIOSH recommendations, and we found no lead contamination on the surfaces that we sampled outside the range, except for the surfaces associated with the ventilation system. However, the local exhaust canopy hood over the wet bullet tank was ineffective in capturing firearm emissions in the breathing zone of the shooter, thereby placing the unit's employees at risk of lead exposure. Employees reported a low level of concern regarding their work-related health, and our environmental sampling results indicate that the risks from chemical exposures are low. The most frequently reported work-related health concerns were stress, allergies perceived to be associated with indoor environmental quality at work, musculoskeletal symptoms, and anxiety. These symptoms are common in workplaces where high workload and time pressure are present [Bongers et al. 1993; NIOSH 2012]. On average, employees reported moderate job stress. We identified strict deadlines, high workload, and lack of resources as factors that contributed to job stress.

Recommendations

On the basis of our findings, we recommend the actions listed below. We encourage the federal crime lab to use a labor-management health and safety committee or working group to discuss our recommendations and develop an action plan. Those involved in the work can best set priorities and assess the feasibility of our recommendations for the specific situation at the lab.

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

Engineering Controls

Engineering controls reduce employees' exposures by removing the hazard from the process or by placing a barrier between the hazard and the employee. Engineering controls protect employees effectively without placing primary responsibility of implementation on the employee.

1. Hire a ventilation engineer to improve the effectiveness of the canopy hood ventilation system over the wet bullet trap.

Administrative Controls

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

1. Increase the frequency of cleaning the canopy hood and other surfaces inside the wet bullet tank to reduce lead dust. Post a dated schedule with a checklist that documents when these structures are cleaned for all to see. Those cleaning this area should be trained and follow procedures to protect themselves from lead exposure.
2. Evaluate workload distribution to ensure that employees have the resources to meet work demands without becoming overwhelmed. Engage employees in discussions about ways to improve workload management.
3. Get feedback from employees regarding job demands and how they affect job stress, morale, and job satisfaction. Use this feedback in determining ways to improve work conditions.
4. Encourage employees to participate in the annual Federal Employee Viewpoint Survey. The survey data can be used to monitor issues related to communication within the agency.
5. Investigate why some employees reported poor communication and interpersonal conflict in the workplace. The Office of Personnel Management offers services for federal government agencies that may be helpful in completing this task at http://www.opm.gov/services-for-agencies/assessment-evaluation/.
6. Encourage employees to use wellness and stress reduction services available through their employee assistance program. For example, employees have access to LifeCare (http://www.lifecare.com/), which offers services in stress reduction, work-life balance, and other wellness programs.

Personal Protective Equipment

Personal protective equipment is the least effective means for controlling hazardous exposures. Proper use of PPE requires a comprehensive program and a high level of employee involvement and commitment. The right PPE must be chosen for each hazard. Supporting programs such as training, change-out schedules, and medical assessment may be needed. Personal protective equipment should not be the sole method for controlling hazardous exposures. Rather, PPE should be used until effective engineering and administrative controls are in place.

1. Require employees to wear polyvinyl alcohol or Silver Shield® gloves when they handle methylene chloride.
2. Require double hearing protection (earmuffs and ear plugs) for impulsive noise generated during weapons firing.

Appendix A: Figures

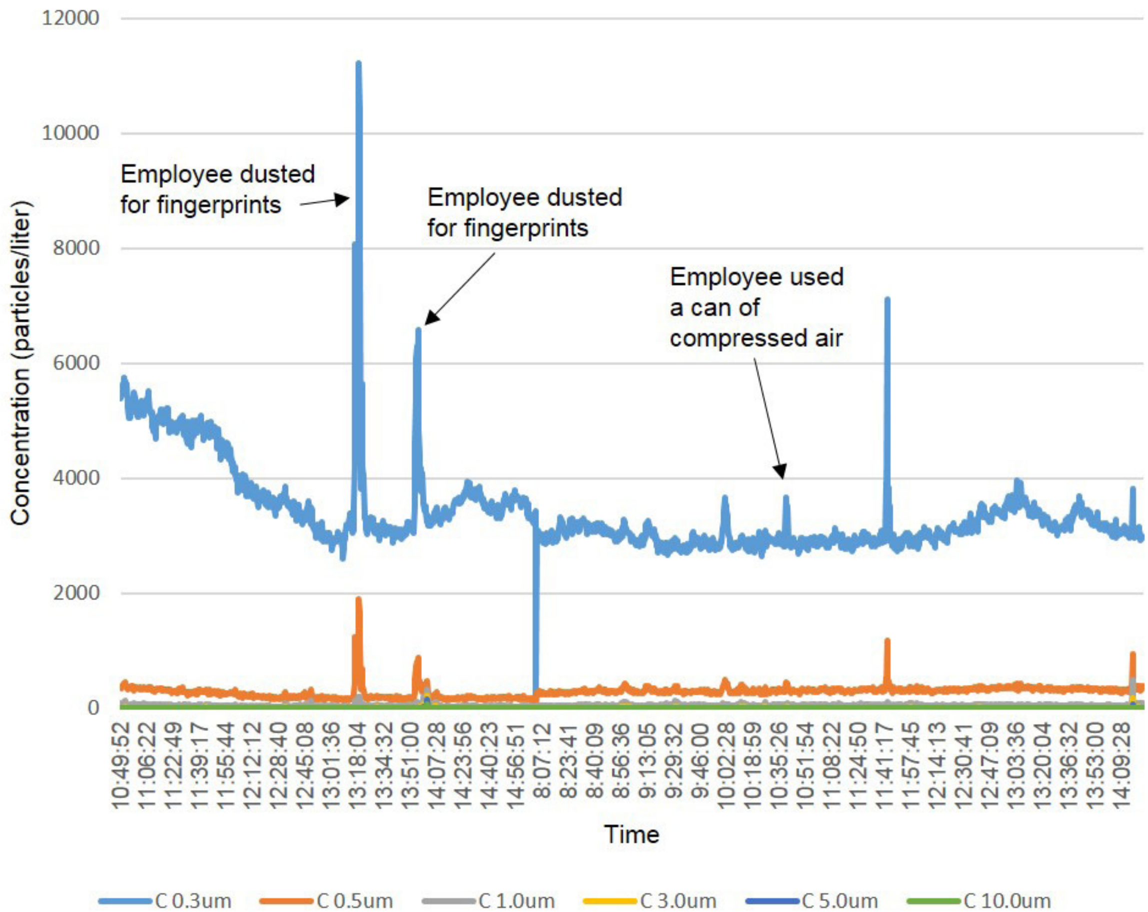

Figure A1. Line graph that depicts the ART Instruments optical particle counter, collected while dusting for fingerprints.

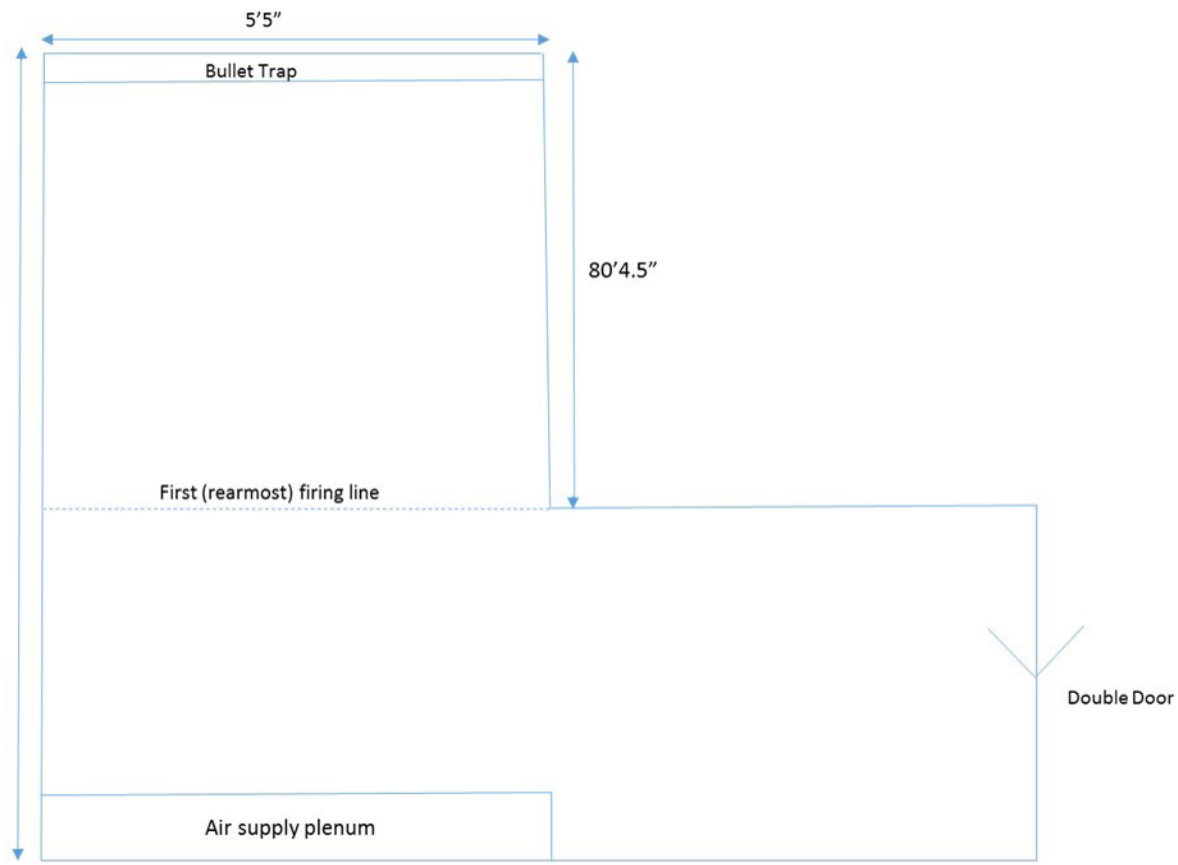

Figure A2. Diagram of the firing range in the firearms and toolmarks unit. The drawing is not to scale. Drawing by NIOSH.

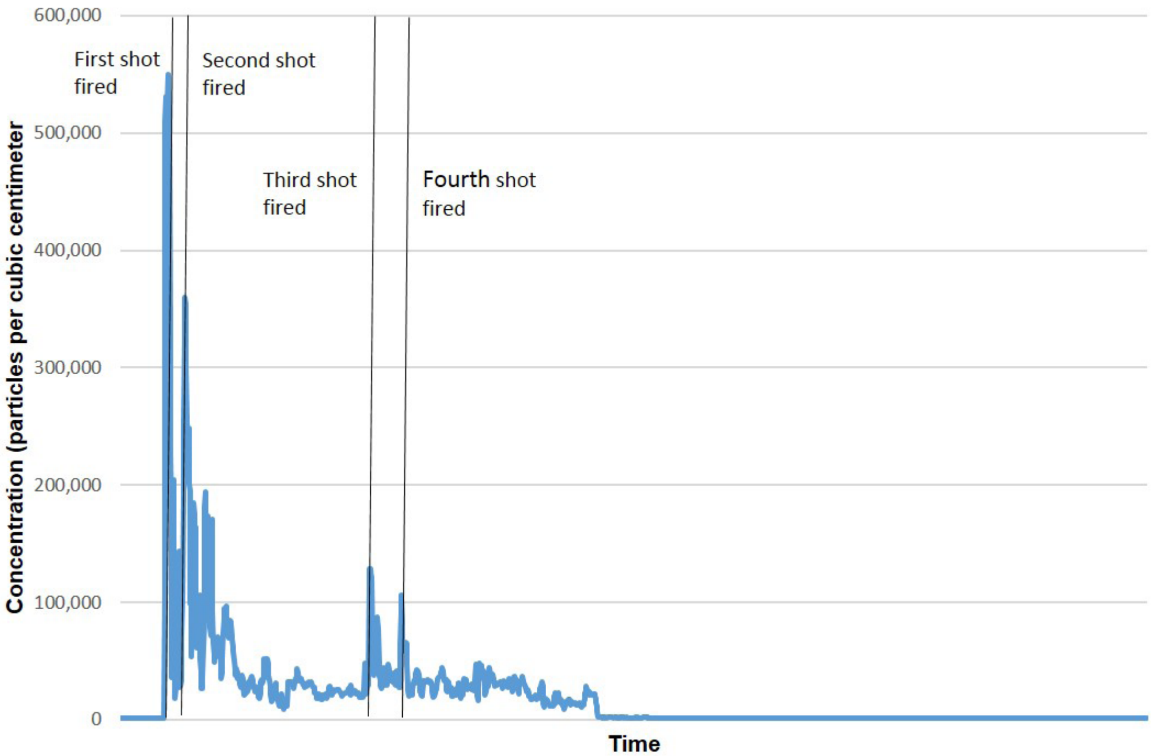

Figure A3. Condensation particle counter results while shooting into wet bullet tank.

Appendix B: Occupational Exposure Limits and Health Effects

NIOSH investigators refer to mandatory (legally enforceable) and recommended OELs for chemical, physical, and biological agents when evaluating workplace hazards. OELs have been developed by federal agencies and safety and health organizations to prevent adverse health effects from workplace exposures. Generally, OELs suggest levels of exposure that most employees may be exposed to for up to 10 hours per day, 40 hours per week, for a working lifetime, without experiencing adverse health effects. However, not all employees will be protected if their exposures are maintained below these levels. Some may have adverse health effects because of individual susceptibility, a pre-existing medical condition, or a hypersensitivity (allergy). In addition, some hazardous substances act in combination with other exposures, with the general environment, or with medications or personal habits of the employee to produce adverse health effects. Most OELs address airborne exposures, but some substances can be absorbed directly through the skin and mucous membranes.

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

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

- The U.S. Department of Labor OSHA PELs (29 CFR 1910 [general industry]; 29 CFR 1926 [construction industry]; and 29 CFR 1917 [maritime industry]) are legal limits. These limits are enforceable in workplaces covered under the Occupational Safety and Health Act of 1970.
- NIOSH RELs are recommendations based on a critical review of the scientific and technical information and the adequacy of methods to identify and control the hazard. NIOSH RELs are published in the *NIOSH Pocket Guide to Chemical Hazards* [NIOSH 2010]. NIOSH also recommends risk management practices (e.g., engineering controls, safe work practices, employee education/training, PPE, and exposure and medical monitoring) to minimize the risk of exposure and adverse health effects.
- Other OELs commonly used and cited in the United States include the TLVs, which are recommended by ACGIH, a professional organization, and the workplace environmental exposure levels (WEELs), which are recommended by the American Industrial Hygiene Association, another professional organization. The TLVs and WEELs are developed by committee members of these associations from a review of the published, peer-reviewed literature. These OELs are not consensus standards. TLVs are considered voluntary exposure guidelines for use by industrial hygienists and others trained in this discipline "to assist in the control of health hazards" [ACGIH 2016].

WEELs have been established for some chemicals "when no other legal or authoritative limits exist" [AIHA 2016].

Outside the United States, OELs have been established by various agencies and organizations and include legal and recommended limits. The Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung (Institute for Occupational Safety and Health of the German Social Accident Insurance) maintains a database of international OELs from European Union member states, Canada (Québec), Japan, Switzerland, and the United States. The database, available at http://www.dguv.de/ifa/GESTIS/GESTIS-Internationale-Grenzwerte-für-chemische-Substanzen-limit-values-for-chemical-agents/index-2.jsp, contains international limits for more than 2,000 hazardous substances and is updated periodically.

OSHA requires an employer to furnish employees a place of employment free from recognized hazards that cause or are likely to cause death or serious physical harm [Occupational Safety and Health Act of 1970 (Public Law 91–596, sec. 5(a)(1))]. This is true in the absence of a specific OEL. It also is important to keep in mind that OELs may not reflect current health-based information.

When multiple OELs exist for a substance or agent, NIOSH investigators generally encourage employers to use the lowest OEL when making risk assessment and risk management decisions. NIOSH investigators also encourage use of the hierarchy of controls approach to eliminate or minimize workplace hazards. This includes, in order of preference, the use of (1) substitution or elimination of the hazardous agent, (2) engineering controls (e.g., local exhaust ventilation, process enclosure, dilution ventilation), (3) administrative controls (e.g., limiting time of exposure, employee training, work practice changes, medical surveillance), and (4) PPE (e.g., respiratory protection, gloves, eye protection, hearing protection). Control banding, a qualitative risk assessment and risk management tool, is a complementary approach to protecting employee health. Control banding focuses on how broad categories of risk should be managed. Information on control banding is available at http://www.cdc.gov/niosh/topics/ctrlbanding/. This approach can be applied in situations where OELs have not been established or can be used to supplement existing OELs.

Lead

Inorganic lead, the type encountered in this forensic lab, is a naturally occurring, soft metal. It exists in many chemical forms, is toxic to all organ systems, and serves no useful purpose in the body. Occupational exposure to inorganic lead, the type used at this forensic lab, occurs via inhalation of lead-containing dust and fume and ingestion of lead particles from contact with lead-contaminated surfaces. Exposure can also occur by transferring lead to the mouth from contaminated hands or cigarettes when careful attention to hygiene, particularly hand washing, is not practiced. In addition to inhaling and ingesting lead, it can also be absorbed through the skin, particularly through damaged skin [Filon et al. 2006; Stauber et al. 1994; Sun et al. 2002].

In the United States, employers in general industry are required by law to follow the OSHA lead standard (29 CFR 1910.1025). This standard was established in 1978 and has not yet been updated to reflect current scientific knowledge regarding the health effects of lead exposure.

Under this standard, the PEL for airborne exposure to lead is 50 micrograms per meter cubed ($\mu g/m^3$) of air for an 8-hour TWA. The standard requires lowering the PEL for shifts that exceed 8 hours, medical monitoring for employees exposed to airborne lead at or above the action level of 30 $\mu g/m^3$ (8-hour TWA), medical removal of employees whose average BLL is 50 µg/dL or greater, and economic protection for medically removed workers. Medically removed workers cannot return to jobs involving lead exposure until their BLL is below 40 µg/dL.

In the United States, other guidelines for lead exposure, which are not legally enforceable, are often followed. Similar to the OSHA lead standard, these guidelines were set years ago and have not yet been updated to reflect current scientific knowledge. NIOSH has an REL for lead of 50 $\mu g/m^3$ averaged over an 8-hour work shift [NIOSH 2010]. ACGIH has a TLV for lead of 50 $\mu g/m^3$ (8-hour TWA), with worker BLLs to be controlled to, or below, 30 µg/dL. The ACGIH designates lead as an animal carcinogen [ACGIH 2016]. In 2013, the California Department of Public Health recommended that California OSHA lower the PEL for lead to 0.5 to 2.1 $\mu g/m^3$ (8-hour TWA) to keep BLLs below the range of 5 to 10 µg/dL [Billingsley 2013].

Neither NIOSH nor OSHA has established surface contamination limits for lead in the workplace. The U.S. Environmental Protection Agency and Housing and Urban Development limit lead on surfaces in public buildings and child-occupied housing to less than 40 micrograms of lead per square foot [EPA 1998; HUD 2012]. OSHA requires in its substance-specific standard for lead that all surfaces be maintained as free as practicable of accumulations of lead [29 CFR 1910.1025(h)(1)]. An employer with workplace exposures to lead must implement regular and effective cleaning of surfaces in change areas, storage facilities, and lunchroom/eating areas to ensure they are as free as practicable from lead contamination.

Health Effects

The PEL, REL, and TLV may prevent overt symptoms of lead poisoning, but do not protect workers from lead's contributions to conditions such as hypertension, renal dysfunction, and reproductive and cognitive effects [Brown-Williams et al. 2009; Institute of Medicine 2012; Schwartz and Hu 2007; Schwartz and Stewart 2007]. Generally, acute lead poisoning with symptoms has been documented in persons having BLLs above 70 µg/dL. These BLLs are rare today in the United States, largely as a result of workplace controls put in place to comply with current OELs. When present, acute lead poisoning can cause myriad adverse health effects including abdominal pain, hemolytic anemia, and neuropathy. In very rare cases, lead poisoning has progressed to encephalopathy and coma [Moline and Landrigan 2005].

People with chronic lead poisoning, which is more likely at current occupational exposure levels, may not have symptoms, or they may have nonspecific symptoms that may not be recognized as being associated with lead exposure. These symptoms include headache, joint and muscle aches, weakness, fatigue, irritability, depression, constipation, anorexia, and abdominal discomfort [Moline and Landrigan 2005].

The National Toxicology Program recently released a monograph on the health effects of low-level lead exposure [NTP 2012]. For adults, they concluded the following about the evidence regarding health effects of lead (Table B1).

Table B1. Evidence regarding health effects of lead in adults

Health area	NTP conclusion	Principal health effects	Blood lead evidence
Neurological	Sufficient	Increased incidence of essential tremor	< 10 µg/dL
	Limited	Psychiatric effects, decreased hearing, decreased cognitive function, increased incidence of amyotrophic lateral sclerosis	< 10 µg/dL
	Limited	Increased incidence of essential tremor	< 5 µg/dL
Immune	Inadequate		Unclear
Cardiovascular	Sufficient	Increased blood pressure and increased risk of hypertension	< 10 µg/dL
	Limited	Increased cardiovascular-related mortality and electrocardiography abnormalities	< 10 µg/dL
Renal	Sufficient	Decreased glomerular filtration rate	< 5 µg/dL
Reproductive	Sufficient	Women: reduced fetal growth	< 5 µg/dL
	Sufficient	Men: adverse changes in sperm parameters and increased time to pregnancy	≥ 15–20 µg/dL
	Limited	Women: increase in spontaneous abortion and preterm birth	< 10 µg/dL
	Limited	Men: decreased fertility	≥ 10 µg/dL
	Limited	Men: spontaneous abortion in partner	≥ 31 µg/dL
	Inadequate	Women and men: stillbirth, endocrine effects, birth defects	Unclear

Various organizations have assessed the relationship between lead exposure and cancer. According to the Agency for Toxic Substances and Disease Registry [ATSDR 2007] and the National Toxicology Program [NTP 2011], inorganic lead compounds are reasonably anticipated to cause cancer in humans. The International Agency for Research on Cancer classifies inorganic lead as probably carcinogenic to humans [WHO 2006]. According to the American Cancer Society [ACS 2011], some studies show a relationship between lead exposure and lung cancer, but these results might be affected by exposure to cigarette smoking and arsenic. Some studies show a relationship between lead and stomach cancer, and these findings are less likely to be affected by the other exposures. The results of studies looking at other cancers, including brain, kidney, bladder, colon, and rectum, are mixed.

Take-home Contamination

Occupational exposures to lead can result in exposures to household members, including children, from take-home contamination. Take-home contamination occurs when lead dust is transferred from the workplace on employees' skin, clothing, shoes, and other personal items to their vehicle and home [Centers for Disease Control and Prevention 2009, 2012].

The Centers for Disease Control and Prevention considers a BLL in children of 5 µg/dL or higher as a reference level above which public health actions should be initiated and states that no safe BLL in children has been identified [Centers for Disease Control and Prevention 2013a].

The U.S. Congress passed the Workers' Family Protection Act in 1992 (29 U.S.C. 671a). The Act required NIOSH to study take-home contamination from workplace chemicals and substances, including lead. NIOSH found that take-home exposure is a widespread problem [NIOSH 1995]. Workplace measures effective in preventing take-home exposures were (1) reducing exposure in the workplace, (2) changing clothes before going home and leaving soiled clothing at work for laundering, (3) storing street clothes in areas separate from work clothes, (4) showering before leaving work, and (5) prohibiting removal of toxic substances or contaminated items from the workplace. NIOSH noted that preventing take-home exposure is critical because decontaminating homes and vehicles is not always effective. Normal house cleaning and laundry methods are inadequate, and decontamination can expose the people doing the cleaning and laundry.

Formamide

Formamide has a NIOSH REL and ACGIH TLV of 10 ppm and a skin notation. A skin notation indicates that this chemical has a potentially significant contribution to the overall exposure through contact with the skin. It can cause irritation to the eyes, skin, and mucous membranes [ACGIH 2016; NIOSH 2016].

Methylene Chloride

Methylene chloride is metabolized by the body to carbon monoxide and, with high exposures, can cause carbon monoxide poisoning [Fagin et al. 1980]. Prolonged skin contact can result in skin irritation or chemical burns [Wells and Waldron 1984]. Exposure to methylene chloride via inhalation and skin exposure may cause eye and skin irritation; weakness, exhaustion, drowsiness, or dizziness; numbness and tingling of limbs; and nausea [NIOSH 1996, 2010]. It is classified by the International Agency for Research on Cancer as group 2, possibly carcinogenic to humans [IARC 1999]. OSHA has established a PEL of 25 ppm as an 8-hour TWA and a STEL of 125 ppm [OSHA 2006]. NIOSH does not have a quantitative OEL but considers methylene chloride an occupational carcinogen [NIOSH 2010]. The ACGIH has established a TLV of 50 ppm as an 8-hour TWA and a STEL of 100 ppm [ACGIH 2016].

Ethyl 2-cyanoacrylate

Ethyl 2-cyanoacrylate, which has an unpleasant, acrid odor, is a common ingredient in adhesive super glues. Neither OSHA nor NIOSH has issued OELs for ethyl 2-cyanoacrylate. The ACGIH TLV of 0.2 ppm is based upon the potential for eye, skin, and upper respiratory tract irritation; dermatitis; and possible respiratory sensitization or asthma [ACGIH 2016]. Although the TLV does not have a skin notation, skin contact has been shown to cause adhesions resulting in tissue damage [ACGIH 2016].

Methanol

Methanol, a clear, highly flammable liquid, is also known as wood alcohol and methyl alcohol. Methanol is quickly absorbed after ingestion or inhalation, and the most characteristic effects of methanol poisoning include visual changes and metabolic acidosis (a systemic lowering of the pH of the blood). Long-term exposure to concentrations ranging from 1,200 to 8,300 ppm can cause impaired vision, while exposure to vapors ranging from 360 to approximately 4,000 ppm may cause blurred vision, headache, dizziness, and nausea [Frederick et al. 1984; NIOSH 1976]. The NIOSH REL and ACGIH TLV are 200 ppm for up to a 10-hour TWA, with a STEL of 250 ppm [ACGIH 2016; NIOSH 2016]. Both NIOSH and ACGIH have a skin notation for methanol, meaning that appropriate protection must be used to avoid skin exposure. The OSHA PEL for methanol is 200 ppm, TWA for up to an 8-hour exposure [OSHA 2015].

Ninhydrin

Little information exists on potential health effects from NIN exposure. Cases of allergic rhinitis and occupational asthma following dermal exposure to NIN solution have been documented [Hytonen et al. 1996; Piirila et al. 1997].

Appendix C: Survey of Chemical Hazards

Form Approved OMB No. 0920-0260
Expires 11/30/2014 **ID______**

U. S. Department of Health and Human Services
U. S. Public Health Service
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

Survey of Chemical Health Hazards
April 2013

FBI Laboratory Division (LD) management asked the National Institute for Occupational Safety and Health to perform an evaluation of **chemical health hazards** at its forensic lab in Quantico, VA. FBI LD management selected employees from each case-working unit who are familiar with the span of work done in that case-working unit to complete this survey. Participation in this survey is voluntary – there is no penalty for choosing not to participate. However, because we will not be able to evaluate all procedures, your responses to this survey will help us prioritize our evaluation on the procedures with greatest potential for exposing employees to chemical health hazards.

Public reporting burden for this collection of information is estimated to average 30 minutes per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. An agency may not conduct or sponsor, and a person is not required to respond to, a collection of information unless it displays a currently valid OMB control number. Send comments regarding this burden estimate or any other aspect of this collection of information including suggestions for reducing this burden to: CDC, Project Clearance Officer, 1600 Clifton Road, MS D-24, Atlanta, GA 30333, ATTN: P.A. (0920-0260). Do not send the completed form to this address.

Q1. Which unit do you work in?

Q2. How long have you worked in the unit?

Q3. What is your job title?

Q4. What are your main job duties?

Q5. Please complete the table below for the **5 procedures** in your case unit that you believe present the **greatest health hazards from chemical exposures** (with #1 being the most hazardous in your opinion). It is all right if you list fewer than 5 procedures.

Procedure name or description (that corresponds with the SOP)	How many times per month is this procedure usually performed?	How many employees perform this procedure?	What substances, chemicals, or mixtures are used or released? (use names as stated in the SOP)	Are employees potentially exposed to any of these chemicals? (regardless of PPE worn)	If yes, please check how they might be exposed. You can check more than one response. (regardless of PPE worn)
1)				◯ Yes ◯ No	◯ Breathing ◯ Skin contact ◯ Eye contact
2)				◯ Yes ◯ No	◯ Breathing ◯ Skin contact ◯ Eye contact
3)				◯ Yes ◯ No	◯ Breathing ◯ Skin contact ◯ Eye contact
4)				◯ Yes ◯ No	◯ Breathing ◯ Skin contact ◯ Eye contact
5)				◯ Yes ◯ No	◯ Breathing ◯ Skin contact ◯ Eye contact

Q6. Please complete the table below for the **5 procedures** that you perform **most FREQUENTLY** (with #1 being the most frequent). Procedures listed in Q5 may be listed again below.

Procedure name or description (that corresponds with the SOP)	How many times per month is this procedure performed?	How many employees perform this procedure?	What substances, chemicals, or mixtures are used or released?	Are employees potentially exposed to any of these chemicals? (regardless of PPE worn)	If yes, please check how they might be exposed. You can check more than one response. (regardless of PPE worn)
1)				◯ Yes ◯ No	◯ Breathing ◯ Skin contact ◯ Eye contact
2)				◯ Yes ◯ No	◯ Breathing ◯ Skin contact ◯ Eye contact
3)				◯ Yes ◯ No	◯ Breathing ◯ Skin contact ◯ Eye contact
4)				◯ Yes ◯ No	◯ Breathing ◯ Skin contact ◯ Eye contact
5)				◯ Yes ◯ No	◯ Breathing ◯ Skin contact ◯ Eye contact

Appendix D: Occupational Exposure Banding

Occupational health and safety professionals often use mandatory and recommended OELs to help ensure that employees are not overexposed to potentially hazardous chemicals. The use and importance of OELs are described in detail in Appendix B. Typically, occupational health and safety practitioners assess workplace exposures and compare the results of personal breathing zone air monitoring to authoritative OELs. Workplace exposure concentrations that exceed or approach the OEL are addressed by implementing the hierarchy of controls (see Appendix B). However, many commonly used chemicals do not have an OEL assigned by an authoritative body, and the number of chemicals without OELs is increasing as the introduction of new chemicals into commerce outpaces OEL development. Therefore, in the absence of applicable OELs, NIOSH has proposed a draft risk management process called occupational exposure banding [McKernan and Seaton 2014]. We used this approach to review, prioritize, and select lab procedures involving potentially hazardous chemicals that did not have OELs. Table D1 shows how the hazard codes and categories correspond to OEL ranges and exposure bands.

In its simplest terms, the draft NIOSH occupational exposure banding process uses qualitative and quantitative data to assign chemicals to OEBs. Each band represents a range of inhalation-based concentration levels that is expected to contain a health protective exposure limit for chemicals that are assigned to that band. The draft NIOSH occupational exposure banding process is three-tiered, with each successive tier requiring additional chemical information. Tier 1 of the draft NIOSH process has the fewest data requirements and can be performed rapidly for a large number of chemicals. Tiers 2 and 3 require more data and time to complete, but often provide the user with the confidence that the chemical being assessed is assigned to the correct exposure band [McKernan et al. 2016]. Tier 1 of the draft NIOSH occupational exposure banding process aligns with the Globally Harmonized System of Classification and Labelling of Chemicals (GHS), an international system developed to standardize the way chemical hazards are designated.

As described previously in Methods, one objective of this evaluation was to prioritize procedures that posed the greatest health risk to the crime lab employees. One of the factors in this prioritization process was determining the OEL ranking (OEL_{RANK}), a numerical score based on the lowest full-shift recommended or mandatory OELs for the chemicals used in the procedure. For chemicals that did not have an OEL we followed Tier 1 in the draft NIOSH occupational exposure banding process. We used hazard codes and hazard categories from the GESTIS Substance Database (http://gestis-en.itrust.de/) and entered these into a spreadsheet. We designed the spreadsheet to automatically compare the hazard codes from the GHS system to the draft NIOSH Tier 1 criteria (Table E1) and assign an OEB for the chemical. We then used the OEB (Table D2) to calculate the OEL_{RANK}. Chemicals with no hazard codes or categories in GESTIS were assigned an OEL_{RANK} of 3.

Table D1. Assigning an OEB to chemicals without OELs

Preliminary NIOSH tier 1 criteria*		C	D	E
OEL ranges	Particle	> 0.1 and ≤ 1 milligrams per meter cubed (mg/m^3)	> 0.01 ≤ 0.1 mg/m^3	≤ 0.01 mg/m^3
	Vapor	> 1 ≤ 10 ppm	> 0.1 ≤ 1 ppm	≤ 0.1 ppm
Acute toxicity		H301 Category 3 H302 Category 4	H300 Category 2	H300 Category 1
		H331 Category 3 H332 Category 4	H330 Category 2	H330 Category 1
		H311 Category 3 H312 Category 4	H310 Category 2	H310 Category 1
Skin corrosion/irritation		H315 Category 2	—	H314 Category 1, 1A, 1B, or 1C
Serious eye damage/ eye irritation		H319 Category 2, 2A or 2B	—	H318 Category 1
Respiratory and skin sensitization		H317 Category 1B (skin)	H317 Category 1 or 1A	—
		—	H334 Category1B	H334 Category 1 or 1A
Germ cell mutagenicity		—	H341 Category 2	H340 Category 1, 1A or 1B
Carcinogenicity		—	—	H350 Category 1, 1A, or 1B H351 Category 2
Toxic to reproduction		H361 *(including H361f, H361d, and H361fd)* Category 2	H360 *(including H360f, H360d, and H360fd)* Category 1B	H360 *(including H360f, H360d, and H360fd)* Category 1 or 1A
Specific target organ toxicity		H371 Category 2 H373 Category 2	—	H370 Category 1 H372 Category 1

*NIOSH draft Tier 1 criteria as of July 2016

Table D2. Results of the Tier 1 exposure banding process for chemicals without OELs

Chemical name	Chemical name (as listed in GESTIS or NIOSH Pocket Guide)	Chemical abstracts service number	Hazard codes (H-code)	Tier 1 band
Tetramethylbenzidine	3,3',5,5'-Tetramethylbenzidine	54827-17-7	Not a dangerous substance according to GHS	Not banded
Ferrous ammonium sulfate	Ammonium iron (II) sulfate (hexahydrate)	7783-85-9	No H codes in GESTIS	Not banded
Ferrous ammonium sulfate	Ammonium iron (II) sulfate (anhydrous)	10045-89-3	No H codes in GESTIS	Not banded
N-dodecylamine acetate	—	2016-56-0	Chemical not found in GESTIS	Not banded
DFO	1,8-diazafluoren-9-one	54078-29-4	Chemical not found in GESTIS	Not banded
Bismuth nitrate pentahydrate	—	10035-06-0	Chemical not found in GESTIS	Not banded
A-naphthoflavone	—	604-59-1	Chemical not found in GESTIS	Not banded
Amido black	—	1064-48-8	Chemical not found in GESTIS	Not banded
7-P-methoxybenzylamine-4-nitorbenz-2 oxa-1-2-diazole (MBO)	4-(4-methoxybenzylamino)-7-nitrobenzofurazan	33984-50-8	Chemical not found in GESTIS	Not banded
Phenolphthalein	Phenolphthalein	77-09-8	350 341 361f	D
Cyanoacrylate	Ethyl 2-cyanoacrylate	7085-85-0	319 315 335	C
Maleic acid	—	110-16-7	302 315 319 335 317	C
Ninhydrin	—	485-47-2	302 315 319 335	C
50% ammonium hydroxide solution	Ammonium hydroxide	1336-21-6	226 314	C
Citric acid	Citric acid (anhydrous)	77-92-9	318	C
Citric acid	Citric acid (monohydrate)	5949-29-1	318	C
Liquid nitrogen	Nitrogen	7727-37-9	280	Not banded

Appendix E: Numerical Scores used to Prioritize Tasks

Equation 1: $Frequency_{RANK}+Exposure_{RANK}+Number_{RANK}+OEL_{RANK}=Total_{RANK}$

Frequency rank: the frequency that the procedure is performed

1 = once or less a month
2 = weekly or biweekly
3 = multiple times a month
4 = daily
5 = multiple times a day

Exposure rank: the potential for employee exposure and if appropriate controls were in place. If the survey indicated employees were potentially exposed, how they were exposed (breathing, skin, or both).

1 = no potential for exposure
2 = low potential for exposure, and appropriate controls are listed
3 = low potential for exposure, but exposure likely because of no or insufficient controls listed
4 = potential for exposure indicated via one route of exposure
5 = potential for exposure indicated via one or more routes of exposure

Number rank: the number of potentially exposed employees

1 = 1–5 employees
2 = 6–9 employees
3 = 10–14 employees
4 = 15–19 employees
5 = 20 or more employees

OEL rank: the OELs for each of the chemicals used in the workplace. For chemicals without authoritative OELs we used OEBs. In cases where there was insufficient information to assign an OEB, an OEL rank of 3 was assigned. The highest ranked chemical was used to determine OEL rank.

1 = > 100 µg/m^3 or > 100 ppm or OEB A*
2 = > 10 and ≤ 100 µg/m^3 or > 10 and ≤ 100 ppm or OEB B
3 = > 1 and ≤ 10 µg/m^3 or > 1 and ≤ 10 ppm or OEB C or unable to be banded
4 = > 0.1 and ≤ 1 µg/m^3 or > 0.1 and ≤ 1 ppm or OEB D
5 = ≤ 0.1 µg/m^3 or ≤ 0.1 ppm or OEB E

*The exposure ranges for the OELs are not the same as the exposure ranges used in the preliminary NIOSH occupational exposure banding guidance.

Appendix F: Summary of Scoring for Top 25 Procedures

Table F1. Risk ranking of forensic procedures

Overall rank	CWU	Procedure	Frequency rank	Employee # rank	Exposure rank	OEL rank	Total score	Primary chemicals of concern
1	LPOU	1,8- Diazafluoren-9-one (DFO)	5	5	5	3	18	Dimethyl formamide
2	LPOU	Cyanoacrylate (superglue) fuming	5	5	4	3	17	Ethyl cyanoacralate
3	LPOU	Ninhydrin (petroleum ether base)	5	5	4	3	17	NIN
4	mDNAU	DNA amplification and sequencing	5	5	4	3	17	Formamide
5	mDNAU	DNA extraction	5	5	4	3	17	Phenol, Chloroform
6	LPOU	RAM (Cyanoacrylate dye stain)	5	5	4	4	18	RAM
7	nDNAU	Confirmatory of ID of blood	5	3	4	4	16	Pyridine
8	nDNAU	Confirmatory blood identification using takayama hemochromogen test	5	4	3	4	16	Hydrogen peroxide
9	OPU	Laser cutting plastic	5	2	5	4	16	Plastic emissions
10	OPU	Painting	5	2	5	4	16	Solvents
11	LPOU	Iodine fuming	1	5	4	5	15	Iodine
12	OPU	Wood cutting	5	2	5	3	15	Wood dust
13	TEU	Scraping	5	3	5	2	15	Particulate
14	FDDU	Electrophoresis plate reagent preparation (automated)	5	3	4	3	15	Formamide

Table F1, continued. Risk ranking of forensic procedures.

Overall rank	CWU	Procedure	Frequency Rank	Employee # Rank	Exposure Rank	OEL Rank	Total Score	Primary chemicals of concern
15	nDNAU	Extracting DNA	5	4	2	3	14	Phenol, Chloroform
16	LPOU	Iodine spray reagent	1	5	3	5	14	Iodine, Methylene chloride
17	QDU	Detecting clandestine writing	1	3	5	5	14	Iodine
18	nDNAU	Differential extraction and purification of DNA	5	4	2	3	14	Phenol, Chloroform
19	FDDU	Automated electrophoresis plate preparation	5	2	4	3	14	Formamide
20	FDDU	Automated mastermix addition (PCR setup)	5	2	4	3	14	Formamide
21	TEU	Examining hairs/fibers on glass microscope slides	5	2	4	3	14	Xylene, toluene, isobutyl methacrylate
22	nDNAU	Capillary electrophoresis of PCR products using 2130xl	5	3	2	3	13	Formamide
23	nDNAU	Confirmatory of ID of blood	2	4	3	4	13	Sodium hydroxide
24	nDNAU	Presumptive blood testing	2	4	3	4	13	Ethyl alcohol, Sodium hydroxide
25	nDNAU	Presumptive blood testing	5	3	1	4	13	Phenolphthalein

mDNAU = Mitochondrial Deoxyribonucleic Acid Unit

nDNAU = Nuclear Deoxyribonucleic Acid Unit

FDDU = Federal Deoxyribonucleic Acid Database Unit

LPOU = Latent Prints Operations Unit

OPU = Operational Projects Unit

QDU = Questioned Documents Unit

TEU = Trace Evidence Unit

References

ACGIH [2016]. 2016 TLVs® and BEIs®: threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

ACS [2011]. Lead. Atlanta, GA: American Cancer Society, http://www.cancer.org/cancer/cancercauses/othercarcinogens/athome/lead.

AIHA [2016]. AIHA 2016 emergency response planning guidelines (ERPG) & workplace environmental exposure levels (WEEL) handbook. Fairfax, VA: American Industrial Hygiene Association.

ATSDR (Agency for Toxic Substances and Disease Registry) [2007]. Toxicological profile for lead. Atlanta, GA: U.S. Department of Health and Human Services.

ATSDR [2015]. Medical management guidelines for methylene chloride, http://www.atsdr.cdc.gov/mmg/mmg.asp?id=230&tid=42.

Billingsley KJ [2013]. Letter of September 30, 2013, from KJ Billingsley, California Department of Public Health, to Juliann Sum, Division of Occupational Safety and Health (Cal/OSHA), California Department of Industrial Relations.

Bongers PM, de Winter CR, Kompier MAJ, Hildebrandt VH [1993]. Psychosocial factors at work and musculoskeletal disease. Scand J Work Env Health *19*(5):297–312.

Brown-Williams H, Lichterman J, Kosnett M [2009]. Indecent exposure: lead puts workers and families at risk. Health Research in Action, University of California, Berkeley. Perspectives *4*(1):1–9.

Centers for Disease Control and Prevention [2009]. Childhood lead poisoning associated with lead dust contamination of family vehicles and child safety seats — Maine, 2008. MMWR *58*(32):890–893.

Centers for Disease Control and Prevention [2012]. Take-home lead exposure among children with relatives employed at a battery recycling facility — Puerto Rico, 2011. MMWR *61*(47):967–970.

Centers for Disease Control and Prevention [2013]. Blood lead levels in children aged 1–5 years — United States, 1999–2010. MMWR *62*(13):245–248.

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

Clark MW, Warren BA, Hagen PT, Johnson BD, Jenkins SM, Werneburg BL, Olsen KD [2011]. Stress level, health behaviors, and quality of life in employees joining a wellness center. Am J Health Promot *26*(1):257–285.

De Dreu CKW, van Dierendonck D, De Best-Waldhober M [2007]. Conflict at work and individual well-being. In: Schabracq MJ, Winnubst JAM, Cooper CL, eds. The handbook of work and health psychology. 2nd ed. West Sussex, England: John Wiley and Sons, Ltd, pp. 495–515.

EPA (Environmental Protection Agency) [1998]. Risk analysis to support standards for lead in paint, dust, and soil. EPA Publication EPA-747-R097-006. Washington, DC, http://www2.epa.gov/lead/risk-analysis-support-standards-lead-paint-dust-and-soil-volume-i-chapters-1-7-and-appendix-epa.

Fagin J, Bradley J, Williams D [1980]. Carbon monoxide poisoning secondary to inhaling methylene chloride. Br Med J *281*(6253):1461.

Filon FL, Boeniger M, Maina G, Adami G, Spinelli P, Damian A [2006]. Skin absorption of inorganic lead (PbO) and the effect of skin cleansers. J Occup Environ Med *48*(7):692–699.

Frederick LJ, Schulte PA, Apol A [1984]. Investigation and control of occupational hazards associated with the use of spirit duplicators. Am Ind Hyg Assoc J *45*(1):51–55.

HUD [2012]. Guidelines for the evaluation and control of lead-based paint hazards in housing, http://portal.hud.gov/hudportal/HUD?src=/program_offices/healthy_homes/lbp/hudguidelines.

Hytonen M, Martimo KP, Estlander T, Tupasela O [1996]. Occupational IgE-mediated rhinitis caused by ninhydrin. Allergy *51*(2):114–116.

IARC [1999]. IARC monographs on the evaluation of the carcinogenic risk of chemicals to humans: re-evaluation of some organic chemicals, hydrazine, and hydrogen peroxide. Volume 71. Lyon, France: World Health Organization, International Agency for Research on Cancer, http://monographs.iarc.fr/ENG/Monographs/vol71/volume71.pdf.

Institute of Medicine [2012]. Potential health risks from recurrent lead exposure of DOD firing range personnel. Washington, DC: National Academies Press.

McKernan LT, Seaton M [2014]. The banding marches on. Synergist *25*(5):44–46.

McKernan LT, Seaton M, Gilbert S [2016]. The NIOSH occupational exposure banding decision logic. Synergist *27*(3):24–27.

Moline JM, Landrigan PJ [2005]. Lead. In: Rosenstock L, Cullen MR, Brodkin CA, Redlich CA, eds. Textbook of clinical occupational and environmental medicine. 2nd ed. Philadelphia, PA: Elsevier Saunders, pp. 967–979.

Murphy WJ, Flamme GA, Meinke DK, Sondergaard J, Finan DS, Lankford JE, Khan A, Stewart M [2012]. Measurement of impulse peak insertion for four hearing protection devices in field conditions. Int J Aud *51*:S31–S42.

NIOSH [1976]. Criteria for a recommended standard: occupational exposure to methyl alcohol. Washington, DC: U.S. Department of Health, Education, and Welfare, Center for Disease Control, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 76-148.

NIOSH [1995]. Report to Congress on the workers' home contamination study conducted under the Workers' Family Protection Act 29 U.S.C. 671a. 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. 95-123, http://www.cdc.gov/niosh/docs/95-123/.

NIOSH [1996]. Methylene chloride: immediately dangerous to life or health concentration documentation, http://www.cdc.gov/niosh/idlh/75092.HTML.

NIOSH [1999]. Stress…at work. 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. 99-101.

NIOSH [2009]. NIOSH alert: preventing occupational exposures to lead and noise at indoor firing ranges. By Kardous CA, King BF, Khan A, Whelan EA, Tubbs RL, Barsan ME, Crouch KG, Murphy WJ, Willson RD, Esswein EJ, Boeniger MF. 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. 2009-136, http://www.cdc.gov/niosh/docs/2009-136/pdfs/2009-136.pdf.

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

NIOSH [2012]. Lighting, indoor environmental quality concerns and job stress at a call center – California. By Wiegand DM, Ramsey JG, Burr GA, Choi 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 2012-0081-3169, https://www.cdc.gov/niosh/hhe/reports/pdfs/2012-0081-3169.pdf.

NIOSH [2013]. Comparison of two acoustic test fixtures for measurement of impulse peak insertion loss. By Khan A, Fackler CJ, Murphy WJ. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, EPHB-350-13a, http://www.cdc.gov/niosh/surveyreports/pdfs/350-13a.pdf.

NIOSH [2014]. Evaluation of job stress and morale at a federal law enforcement agency's district facilities. By Wiegand DM, Brown SM. 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 2012-0160-3212, https://www.cdc.gov/niosh/hhe/reports/pdfs/2012-0160-3212.pdf.

NIOSH [2016]. NIOSH manual of analytical methods (NMAM®). 4th ed. Schlecht PC, O'Connor PF, eds. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication 94-113 (August 1994); 1st Supplement Publication 96-135; 2nd Supplement Publication 98-119; 3rd Supplement 2003-154, http://www.cdc.gov/niosh/docs/2003-154/.

Nixon AE, Mazzola JJ, Bauer J, Krueger JR, Spector PE [2011]. Can work make you sick? A meta-analysis of the relationships between job stressors and physical symptoms. Work Stress *25*(1):1–22.

NTP [2011]. Report on carcinogens, 12th ed. Research Triangle Park, NC: U.S. Department of Health and Human Services, National Institutes of Health, National Institute of Environmental Health Sciences, National Toxicology Program, http://ntp.niehs.nih.gov/ntp/roc/twelfth/profiles/Lead.pdf.

NTP [2012]. Monograph on the health effects of low-level lead. Research Triangle Park, NC: U.S. Department of Health and Human Services, National Institutes of Health, National Institute of Environmental Health Sciences, National Toxicology Program.

OSHA [2006]. Occupational Safety and Health Standards, Subpart Z, Toxic and hazardous substances, 1910.1000 table Z-1, Limits for air contaminants, https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9992&p_text_version=FALSE.

OSHA [2016]. OSHA sampling and analytical methods. Hendricks W, ed. Salt Lake City, UT: U.S. Department of Labor, Occupational Safety and Health Administration, http://www.osha.gov/dts/sltc/methods/index.html.

Piirila P, Estlander T, Hytonen M, Keskinen H, Tupasela O, Tuppurainen M [1997]. Rhinitis caused by ninhydrin develops into occupational asthma. Eur Respir J *10*(8):1918–1921.

Schwartz BS, Hu H [2007]. Adult lead exposure: time for change. Environ Health Perspect *115*(3):451–454.

Schwartz BS, Stewart WF [2007]. Lead and cognitive function in adults: a question and answers approach to a review of the evidence for cause, treatment, and prevention. Int Rev Psychiatry *19*(6):671–692.

Stauber JL, Florence TM, Gulson B, Dale L [1994]. Percutaneous absorption of inorganic lead compounds. Sci Total Environ *145*(1–2):55–70.

Sun CC, Wong TT, Hwang YH, Chao KY, Jee SH, Wang JD [2002]. Percutaneous absorption of inorganic lead compounds. Am Ind Hyg Assoc J *63*(5):641–646.

Wells GG, Waldron HA [1984]. Methylene chloride burns. Br J Ind Med *41*(3):420.

WHO [2006]. IARC monographs on the evaluation of carcinogenic risks to humans volume 87. Inorganic and organic lead compounds. Summary of data reported and evaluation. Geneva, Switzerland: World Health Organization.

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