HHS Public Access
Author manuscript
New Solut. Author manuscript; available in PMC 2022 May 23.

Published in final edited form as:
New Solut. 2021 November ; 31(3): 315–329. doi:10.1177/10482911211039566.

Occupational Safety and Health and Illicit Opioids: State of the Research on Protecting Against the Threat of Occupational Exposure

Casey Basham[1], **Audrey Cerles**[1], **Margaret Rush**[1], **Marissa Alexander-Scott**[2], **Lee Greenawald**[3], **Sophia Chiu**[4], **Kendra Broadwater**[4], **Deborah Hirst**[4], **John Snawder**[4], **Jennifer Roberts**[4], **Angela Weber**[5], **Martha Knuth**[6], **Rocco Casagrande**[1]

[1]Gryphon Scientific LLC, Takoma Park, MD, USA

[2]Health Effects Laboratory, National Institute for Occupational Safety and Health, Cincinnati, OH, USA

[3]National Institute for Occupational Safety and Health, Pittsburg, PA, USA

[4]National Institute for Occupational Safety and Health, Cincinnati, OH, USA

[5]National Institute for Occupational Safety and Health, Atlanta, GA, USA

[6]Stephen B Thacker Library, Centers for Disease Control and Prevention, Atlanta, GA, USA

Abstract

The nationwide opioid crisis continues to affect not only people who use opioids but also communities at large by increasing the risk of accidental occupational exposure to illicit opioids. In addition, the emergence of highly potent synthetic opioids such as fentanyl and carfentanil increases the need to protect workers who may encounter unknown drug substances during job activities. To support the National Institute for Occupational Safety and Health Opioids Research Gaps Working Group, we examined the state of the literature concerning methods to protect workers against accidental occupational exposure to illicit opioids, and have identified unmet research needs concerning personal protective equipment, decontamination methods, and engineering controls. Additional studies are needed to overcome gaps in technical knowledge about personal protective equipment, decontamination, and control methods, and gaps in understanding how these measures are utilized by workers. Increasing our knowledge of how to protect against exposure to illicit opioids has the potential to improve occupational health across communities.

Corresponding Author: Casey Basham, Gryphon Scientific LLC, 6930 Carroll Ave #810, Takoma Park, MD 20912, USA. cbasham@gryphonscientific.com.

Declaration of Conflicting Interests
The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Disclaimer
The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention (NIOSH/CDC). Mention of any company or product does not constitute endorsement by NIOSH/CDC.

Keywords

opioids; occupational; exposure; protection

Introduction

The nationwide opioid crisis continues to affect not only people who use opioids but also their communities at large by potentially increasing the risk of accidental occupational exposure to illicit opioids. First responders, educational staff, hotel staff, airline flight crews, public transit workers, librarians, food service workers, and others may be at risk for encountering opioids and adverse health effects from suspected occupational exposures to illicit opioids and one study found that people in some of these occupations encounter opioids and drug paraphernalia at their place of work.[1,2] In addition, the emergence of highly potent synthetic opioids other than methadone such as fentanyl and its various analogs ("fentanyls") and carfentanil increases the need to protect workers, such as first responders, who may encounter unknown drug substances in the course of their routine job activities.[3] However, misconceptions and disagreements about the risk of occupational exposure and the correct protection methods abound. To address this issue, the National Institute for Occupational Safety and Health (NIOSH) Opioids Research Gaps Working Group seeks to identify areas of research that require further development to help confront the nation's opioid crisis. To support the Working Group, we have examined the state of the literature concerning methods to protect workers against accidental occupational exposure to illicit opioids, including personal protective equipment (PPE), decontamination methods, and engineering controls, with the goal of identifying unmet research needs that, when addressed, may greatly increase occupational health and safety among those at risk.

Approach—Literature Search and Triage

The foundation of our effort to determine research gaps was an extensive literature search for studies published in the last ten years relating to protection from occupational exposure to illicit opioids. Search terms were crafted to target publications relating to PPE, decontamination methods, and engineering controls for illicit opioids. We searched the following databases on 20 February 2020 for the terms related to exposure or monitoring, workers, and opioids including their synonyms, in the title, abstract, keywords, or subject headings: Medline (Ovid), Embase (Ovid), CAB Abstracts (Ovid), Global Health (Ovid), PsycInfo (Ovid), Scopus, the Cochrane Library, Academic Search Complete (Ebsco), CINAHL (Ebsco), ProQuest Central, PubMed Central, ToxNet, Safety Lit, the Homeland Security Digital Library, CDC Stacks, Micromedex, as well as gray literature sources. These searches were limited to those studies published in English from 2010–2020. The search of the literature published in the last ten years returned more than 5500 publications, the majority of which were rejected on title or abstract review because they pertain to the use of opioids for pain management, opioid use and use disorder in the general population, or reversal of an opioid overdose, leaving less than fifteen relevant articles. Given the lack of results in our peer-reviewed literature search, targeted searches and gray literature sources (those sources outside academic journals such as government, academic, and industry publications) were utilized to identify supporting information. We focused our searches on non-healthcare-related occupations and found that the majority of results were related to occupational exposure of first responders. First responders serve important public health and safety functions and their job tasks put them at increased risk of experiencing occupational exposure to illicit drugs, and therefore appear to be the target of a greater amount of research than other occupations. This focus on first responders is reflected in our discussion of the research results, but the knowledge and research gaps concerning protection from opioid exposure discussed below are relevant to any person who may encounter opioids on the job.

Results

Personal Protective Equipment

PPE efficacy—Peer-reviewed and gray literature.—During the defined time frame (2010 to February 2020) of the literature search, we found six publications concerning the use of PPE to reduce occupational exposure to illicit opioids. These six publications did not include any peer-reviewed studies examining the efficacy of PPE against illicit opioids,[a] and indeed this lack of knowledge and data about opioids and PPE has been recognized elsewhere.[3–5] Much of the discussion of PPE is limited to expert commentaries and opinion pieces discussing the current recommendations or the need for PPE more generally (e.g., commentary by Howard and Hornsby-Meyers in *American Journal of Industrial Medicine*[6]; special contribution paper by Lynch et al. in *Prehospital Emergency Care* [5]; brief review by Leen and Juurlink in *Journal of Anesthesia*[7]). In the absence of empirical research, targeted searches were performed to identify studies that support the efficacy of PPE against illicit opioids and the protective value of PPE outside the workplace. In addition, targeted searches identified official recommendations and guidelines issued by a variety of government and professional organizations concerned with work force protection, including:

- National Institute for Occupational Safety and Health (NIOSH)[8]
- U.S. Department of Justice Drug Enforcement Administration (DEA)[9]
- American College of Medical Toxicology and the American Academy of Clinical Toxicology (ACMT/AACT)[10]
- InterAgency Board for Emergency Preparedness and Response (IAB)[11]

The PPE recommended by these organizations is summarized in Table 1, followed by a discussion of the current guidelines and evidence concerning the use of PPE.

Respirators.—Inhalation of aerosolized opioids is considered a primary occupational exposure route of concern.[11] Illicit opioids present on the street may be in powder form, meaning aerosolized opioid powder may be present at a response scene or may be created through response activities, such as handling powders or disturbing surfaces, which may lead to re-aerosilization.[9,12] Airborne particles in the respirable range of less than 10 μm

[a] An additional article was published after our initial literature search and therefore not included in the count of peer-reviewed literature. The draft manuscript was kindly provided by the authors.

in diameter can then be inhaled, though it is uncertain what level of inhalational exposure results in opioid intoxication and how fine drug powders encountered on the street may be.[6]

All of the recommendations identified include some form of respiratory protection based on perceived risk level. For routine activities with opioid indicators (such as pills or paraphernalia), or after observing the presence of any unknown powder, NIOSH and The IAB recommend, at a minimum, donning a N100, P100, or R100[c] filtering facepiece respirator (FFR).[8,11] The ACMT/AACT recommends that responders wear a properly fitted N95 or P100 respirator, while the DEA recommends an N95 FFR.[9,10]

For nonroutine activities where the risk of exposure is moderate, such as in scenes potentially containing large volume storage or distribution, re-aerosolization of opioid powders in containers is an increased concern.[5] As a result, respiratory protection for responders is recommended by NIOSH and the IAB to be at least a P100 FFR (with nonvented or indirect vented goggles for eye protection), an elastomeric half mask air-purifying respirator (APR) with P100 filters, or a full facepiece APR with P100 filters.[8,11] For events with high risk of exposure, such as responses to scenes in opioid milling labs, NIOSH, the IAB, and the DEA recommend that responders should, at the minimum, wear a full facepiece APR with P100 filters, a powered APR (PAPR) with a high-efficiency particulate air (HEPA) filter, or a self-contained breathing apparatus.[8,9,11] In addition, half-facepiece and full-facepiece respirators prevent mucosal exposure as well as inhalation exposure by preventing substances from entering the nose or mouth directly or, for full facepieces, through inadvertent touching of the face with contaminated hands or gloves. Opioids can be efficiently absorbed through mucous membranes of the nose and mouth, so respirators covering the face are an effective barrier to this type of exposure.[6,13]

As noted earlier, there are no publicly available empirical studies directly examining the efficacy of respirators against various forms of opioids. However, based on the anticipated particle size of opioids and the filtration protection offered by NIOSH-approved N/R/P100 particulate filter media NIOSH reported that empirical studies were not critical to show that fentanyl powders would be adequately filtered.[d] NIOSH uses a worst-case penetrating aerosol size of 0.1 to 0.3 μm (i.e., an aerosol size that produces maximum filter penetration) in which the filters must not allow more than 5%, 1%, or 0.03% of particles through the filter for 95, 99, or 100-level of protection.[14] Particulate removal by the filter occurs through several filtration mechanisms.[15] In addition, there were nonpublicly available empirical studies that support NIOSH's recommendations developed for respiratory protection for opioids. In 2020, NIOSH published a study detailing the findings of a hazard assessment to ensure NIOSH-approved chemical, biological, radiological, nuclear (CBRN) canisters (which include a carbon bed sorbent and P100 filter media) remain protective against new and emerging CBRN hazards.[16] The assessment included fentanyl and its analogs, and it was determined that the P100 filter within the CBRN canister would adequately provide protection for these hazards.

---

[c]. N: not resistant to oil; R: resistant to oil; P: oil proof.
[d]. As reported in personal communication with NIOSH staff.

A 1996 study of illicit powders seized in the UK containing between 8% and 85% heroin found the representative particle size to be 45 µm in diameter, with a range of 5.8 to 564 µm.[12] No studies examining the particle size of illicit fentanyl were identified, though particle sizes have been examined in other contexts. A study of fentanyl smoke produced in the lab found particle sizes of 1.07 to 2.05 µm, while a pharmaceutical inhaler dispensing ≥98% pure aerosolized fentanyl produces particle sizes of 1 to 3.5 µm.[17,18] For comparison, a 1998 study of N95 FFRs from various manufacturers using table salt (NaCl) and bacteria of size and shape similar to *Mycobacterium tuberculosis* as the particulate matter found that filtration efficiencies differed between manufacturers, but all were at least 95% efficient for particle sizes of 0.1 to 0.3 µm, and approximately 99.5% efficient or higher for particles 0.75 µm and larger.[19] A 2009 study of NIOSH-approved FFRs found that penetrations from a 0.238 µm diameter polydispersed aerosol test (similar to the NIOSH respirator certification test method) were <1% for N95 FFR models and <0.03% for P100 models, and mono-dispersed aerosol penetration tests showed that the most penetrating particle size was between 0.03 and 0.06 µm for all models tested.[20] From these results, respirators appear to be equally effective for biotic materials, salts, and polymers of similar sizes.

There is no universal agreement among experts regarding selection of an N/R/P-95 versus N/R/P-100 respirator filters for protection against opioids.[3] By definition, N/R/P-95 respirator filters are those that remove at least 95% of a 0.3 µm challenge aerosol, while N/R/P-100 respirator filters are those that remove at least 99.97%, meaning that N/R/P-100 respirator filters theoretically offer greater protection.[21] The particle sizes of heroin and fentanyl identified in this research are well within the expected and tested range of protection of both N95 and P100 particulate respirators. However, the identified studies of particle size may not represent the opioids currently encountered. The particle size of fentanyl smoke produced in the lab or aerosolized in pharmaceutical inhalers is likely much finer than the aerosolized dust found in illicit opioid milling or manufacturing sites, and the particle sizes of heroin samples from more than 20 years ago may not be representative of the particle sizes of opioid powders found today, which often contain mixtures of heroin, fentanyl, and other drugs.[3] In addition, the literature does not compare the efficacy of N versus R versus P respirator filters (N: not resistant to oil; R: resistant to oil; P: oil proof) for protection against opioids, and does not provide information on which type of respirator is most appropriate for various response scenarios based on the likely presence or absence of oily aerosols which may be present in fentanyl precursors.

Gloves.—Transdermal exposure is possible since opioids, particularly fentanyls, can penetrate human skin, and the delivery of illicit opioids by injection poses a risk of exposure through accidental needlesticks.[3,6] Accordingly, all of the recommendations include nitrile gloves to prevent transdermal exposure. Nitrile is well established as being more durable and puncture resistant than latex, and therefore provides a measure of protection (though not full protection) against accidental needlesticks. A study of simulated bloodborne infection through needlestick injury (NSI) found that single-layer nitrile gloves with a thickness of 5.1 mils offered superior protection to single-layer latex gloves with a similar thickness,[22] and a similar study of latex and nitrile dental examination gloves found nitrile to have significantly higher puncture resistance.[23] Although not specific to illicit opioids, these studies support the recommendation of nitrile gloves for handling needles and syringes and for working in situations in which this paraphernalia may be present. In addition, the IAB supports its recommendation of nitrile over latex by noting the large incidence of latex allergy among the U.S. population.[11]

There is limited empirical data for glove performance for protecting against illicit opioid exposure, with only one study from NIOSH evaluating the permeation of fentanyl and carfentanil through commercially available disposable vinyl, latex, and nitrile gloves.[e],[24] Researchers adapted the ASTM International D6978–19 standard for chemotherapy drug glove permeation to test fentanyl hydrochloride and carfentanil hydrochloride solution permeation through multiple disposable glove models, including models in which the manufacturers claim that their gloves offer fentanyl protection. No nitrile glove models showed fentanyl or carfentanil permeation rates above the chemotherapy drug threshold criterion of 0.01 $\mu g/cm^2/min$, thereby meeting the minimum performance requirement. Latex and vinyl glove models exhibited fentanyl and carfentanil permeation rates above this threshold and therefore may fail to provide sufficient protection. These findings support NIOSH's current nitrile glove recommendation. However, the authors note that there is currently no industry standard test method specifically for evaluating gloves and other types of PPE against fentanyl and its analogs, and that standardized methods with opioid-specific detection criteria are needed to fully understand the protection offered by various types of equipment.

Eye protection.—Some form of eye protection, such as safety glasses, goggles, face shields, or full facepiece respirators is included in all identified recommendations. Eye protection is intended to prevent ocular exposure by reducing the likelihood of solid opioid particles or liquid splashes entering the eye, and by preventing workers from touching the eyes with contaminated hands or gloves. However, it is unknown if opioids can be absorbed systemically through the eye.[25] Ocular exposure is considered possible given that opioids can be absorbed through other mucous membranes, and so experts recommend eye protection despite the lack of evidence.[6,13]

Garment-type protectors.—As for gloves, garment-type protectors worn over bare skin are recommended to prevent transdermal exposure and reduce the likelihood of needlesticks. In addition, there is concern that those who encounter opioids on the job may inadvertently carry opioid powder on their clothing into other locations, such as their cars, offices, and homes, perpetuating the risk of exposure to themselves and others.[5] For this reason, all recommendations identified include the use of garment protectors such as coveralls, sleeve protectors, or shoe covers when working in heavily contaminated areas.[8–11]

PPE efficacy—Gaps.—There is a clear lack of data concerning the efficacy of PPE in limiting occupational exposure to illicit opioids, as the literature search returned no peer-reviewed studies on this topic. This lack of scholarship may be due in part to the regulatory and safety challenges of conducting research on illicit drugs as well as reports

[e]. Article published after our initial literature search and therefore not included in the count of peer-reviewed literature. The draft manuscript was kindly provided by the authors.

that are classified (i.e., not available to the public).[26,27] Heroin is a Schedule I drug while fentanyl is a Schedule II, meaning both carry restrictions on their research use.[28]

Moreover, the supposition that these forms of PPE are broadly effective against a wide variety of chemicals may contribute to the perception that further testing against specific illicit opioids is unneeded. In conversation with NIOSH, we were informed that the recommendations made by government and professional organizations were initially largely based on subject matter expertise (where additional empirical studies confirmed recommendations), as well as nonpublicly available reports[29]; clearly, experts consider the use of certain equipment prudent despite limited empirical data for some routes of exposure and the efficacy of some types of PPE against opioids. There are studies (such as those described earlier) that support the efficacy of PPE for worker protection more broadly and the recommended forms of PPE have a long history of successful use in other contexts. Thus, they are trusted by the experts to offer sufficient protection against opioids and may not be an attractive research topic.

Even if existing research on the general operational specifications of equipment is considered sufficient, research on the unique needs of workers who may encounter opioids regularly is a gap. Studies that examine the composition of illicit opioids most prevalent on the street (e.g., substance mixtures, particle sizes), the unique environments in which workers may be exposed (e.g., volume of aerosolized opioids encountered by first responders in milling labs), and the unique stresses placed on PPE during various opioid encounters are lacking. Such studies would ensure that assumptions about PPE efficacy are accurate and that recommendations are tailored to the reality of the user. Further data on routes of exposure, such as ocular and inhalational, and related onset of opioid intoxication for the forms of opioids found on the street are also needed and would better inform PPE recommendations and safety practices across occupations.

PPE knowledge and utilization—Peer-reviewed and gray literature.—The efficacy of PPE depends on proper and consistent use as well as product integrity, and three studies were identified that examine knowledge and utilization of PPE with respect to opioids: two looked at police and other first responders specifically and one looked at state police forensic chemists.

In 2018, NIOSH conducted a Health Hazard Evaluation (HHE) concerning the unintentional opioid exposure among police officers and firefighters during their first responder activities.[30] As part of the study, all on-duty firefighters in an urban Midwest location were asked to complete a written questionnaire that included questions about potential occupational exposure to opioids and PPE availability and use. Of 189 firefighters who participated in the questionnaire, the majority reported the potential for exposure to opioids, including 173 (92%) who recently participated in an opioid overdose response, and 118 (62%) who reported that suspected opioids were visible during the course of their work in the last six months. Concerning PPE availability and use, all firefighters reported that gloves were available when suspected opioids were visible and 92% reported wearing them. However, most firefighters reported never using a respirator (90%) or eye protection (79%) for responses where opioid powder or liquid was visible, even when such equipment was available. The most frequently cited reasons for not wearing PPE included "I did not think it was necessary" and "It was not required." Similarly, other HHEs conducted following incidents where first responders suffered adverse health effects from suspected opioid exposure (based on post-incident interviews and medical records rather than questionnaire methodology as noted above) found that many responders did not wear gloves or respirators despite the presence of suspected opioids, and some wore other PPE such as leather, latex, or Kevlar gloves.[31–33]

The second study was a 2019 survey of 187 New York state law enforcement officers, firefighters, and emergency medical technicians regarding knowledge of fentanyl exposure and PPE.[34] The study found that responders generally agreed with expert risk perceptions of fentanyl but had lower agreement with expert recommendations on PPE. Most respondents understood the need to protect their eyes, nose, and mouth when working with fentanyl and to not disturb fentanyl without PPE. However, 38.5 percent of questionnaire respondents could not identify nitrile as the recommended glove type (placing them at risk of transdermal exposure), with 29.4% being "unsure" and 9.1% believing that latex gloves are preferred. Lastly, of police officers and 55.8% of firefighters and emergency medical services personnel believed that they do not have access to the proper PPE to counter fentanyl exposure.

The third evaluation, a NIOSH HHE, assessed fentanyl, heroin, and nonopioid illicit drug exposures and work practices of drug chemists who worked in state police forensic laboratories.[35] Employees' PPE use was observed during two visits to the laboratories. In between NIOSH visits, management provided additional training on PPE and improved PPE policy enforcement, fit tested all drug chemists for N95 FFRs, and removed non-nitrile gloves from the laboratories. When compared to observations made during the first visit, PPE practices improved: more chemists chose to wear N95 FFRs when handling unknown powders, and all chemists wore eye protection and nitrile gloves when handling evidence. However, gaps remained for respirator storage, maintenance, and replacement.

Given the small number of studies identified in this section, targeted literature searches were conducted to identify studies on PPE knowledge and utilization more generally. Two additional studies were found that examined firefighters' decision-making and use of PPE. Maglio et al. conducted a national study of fire service safety climate to examine the gap between demonstrated safety knowledge and the lack of connection to observed or self-reported safety behaviors in firefighters.[36] This research found three leading reasons for PPE noncompliance that may similarly apply in opioid exposure situations. The first was firefighter identity, described as acceptance of group cultural norms as opposed to acknowledged safety standards. For example, positive perceptions of risk-taking among peers and supervisors and group pressure to appear tough and courageous may make proper PPE use less desirable. The second reason was goal seduction, a term used to define certain situations where firefighters are led to prioritize being "first-in" over their own safety. Lastly, Maglio et al. defined a third reason as situation aversion, which is when firefighters are led away from safe choices because they are inconvenient or uncomfortable, or because they think wearing PPE might invite ridicule from peers. In a second study that conducted a pilot survey of firefighters in the Southeastern United States, similar factors were identified as reasons that firefighters didn't use or misused (including not maintaining) PPE.[37]

PPE knowledge and utilization—Gaps.—The literature search revealed limited research on knowledge and use of PPE to counter illicit opioid exposure. In fact, the authors of the 2019 survey conducted in New York State noted that their study is the first of its kind to explore the risk perceptions and knowledge of first responders with respect to fentanyl exposure.[34] Although other studies were identified that examine barriers to PPE usage more generally, these studies focus only on firefighters and so similar factors may or may not affect PPE-related decision-making among other occupations. Whether the motivations behind PPE use or misuse in other situations apply equally to illicit opioid exposure, and if greater knowledge of the risks posed by opioids can overcome the barriers to use and change patterns of PPE utilization remains unclear. In addition, there is a lack of understanding of how PPE for opioid exposure may interfere with various job duties, particularly the public safety functions of law enforcement and other responders, and these risks and possible mitigation strategies should be identified. Further, there is a gap in research concerning employers' regulatory practices concerning worker protection from occupational exposure to illicit opioids. Research is needed to better understand how employers' administrative policies, trainings, and compliance with existing PPE standards and regulations may impact how and to what extent workers are protected from occupational exposure to illicit opioids. Particularly, knowledge is needed regarding the adoption of respiratory protection programs that include medical clearance, fit testing, and training.

Overall, there is a clear gap in knowledge regarding the proper use of PPE across occupations including employer practices to support proper PPE utilization. Research suggests there may be evidence of nonutilization or improper utilization of PPE among potentially exposed first responder populations,[30–34] and NIOSH is working with fire departments to identify various practices related to PPE.[38] Additional future studies may identify opportunities at the employer and worker level for behavior change methods, including new or modified trainings, to improve occupational safety.

Decontamination and disposal of illicit opioids

Decontamination—Peer-reviewed and gray literature.—The recommendations and guidelines for PPE (NIOSH, DEA, ACMT/AACT, and IAB) described above also contain recommendations for personal and PPE decontamination, and additional recommendations for decontamination were identified from the U.S. *Environmental Protection Agency (EPA) Fact Sheet for Federal OnScene Coordinators: Fentanyl and Fentanyl Analogs*.[39] The decontamination methods recommended by these organizations are summarized in Table 2.

Our search of the literature returned only one study examining environmental decontamination of opioids (a letter to the editor from Froelich et al.), and so we performed additional targeted searches of peer reviewed and gray literature to identify studies that examine personal, equipment, or environmental decontamination methods. Summarized below is the available evidence concerning decontamination and disposal of opioids and the relationship of this evidence to current recommendations.

Personal decontamination.—Alcohols and alcohol-based hand sanitizers are not recommended for personal decontamination because they do not remove illicit opioids from the skin and may increase dermal drug absorption.[8–11,39] Opioids are generally soluble in alcohol, and alcohols have long been used as absorption enhancers for transdermal opioid analgesic patches.[39,40] In contrast, a study by Lent et al. utilized an in vitro static diffusion cell system to examine the percutaneous permeation of carfentanil dissolved in water, ethanol, and two brands of hand sanitizer and found that permeation was fastest for carfentanil in water (3.60×10^{-3}cm/h), followed by hand sanitizer (0.88×10^{-3}cm/h), and slowest for ethanol (0.17×10^{-3}cm/h).[41] Similarly, the permeability coefficient and percent permeation after six hours were highest for carfentanil in water, lowest for ethanol, and intermediate for hand sanitizer. Differences in permeation were observed between the two brands of hand sanitizer tested despite the fact that both contained 70 percent ethanol, indicating that the percentage of water and other ingredients in hand sanitizer may affect dermal absorption. These data indicate that using alcohol-based hand sanitizers for personal decontamination may not pose as great a threat of transdermal exposure as previously assumed, and that the use of water alone may in fact enhance risk more than suspected. However, the laboratory study examined only carfentanil dissolved in liquid, and it is possible that powdered carfentanil may be more easily carried into the skin by alcohol-based hand sanitizer or other liquids relative to the permeation achieved by dry powder on the skin.

However, even if alcohol-based hand sanitizer does not significantly increase dermal absorption, the general solubility of opioids in alcohol means that alcohol-based hand sanitizers may dissolve opioids and spread them over the skin. Since alcohol-based hand sanitizer use is rarely followed by rinsing with water, the sanitizer may then deposit a thin layer of opioid back on the skin as it evaporates rather than removing it. This failure of alcohol-based hand sanitizer to remove opioids from skin may be reason enough to recommend against its use even in the absence of increased dermal absorption, though there are no studies examining the ability of alcohol-based hand sanitizer to remove opioids that can confirm whether alcohol-based hand sanitizer and opioids do in fact simply spread contamination instead of remove it. In addition, while soap and water are often recommended over hand sanitizer, there are no studies examining the efficacy of any type of soap for removing opioids from skin. Overall, the equivocation in the literature regarding the risks associated with hand sanitizer and alcohol, and the lack of studies demonstrating removal of opioids from the skin by any method, suggests that these measures may require closer examination.

Environmental decontamination.—The literature search returned only one study on environmental decontamination, a letter to the editor from Froelich et al. examining the use of OxiClean™ Versatile Stain Remover (a peroxide solution) and tap water for cleaning a surface contaminated with fentanyl or acetylfentanyl.[42] Sections of a laboratory benchtop were sprinkled with 1 mg of fentanyl or acetylfentanyl powder and then sprayed with a cleaning solution, either a 1% solution of OxiClean™ or tap water. Sections were left to sit between zero and 60 minutes and then wiped with a paper towel prior to final swabbing. After cleaning, fentanyl was detected on the water treated sections at zero and fifteen minutes, but was not detected on the zero or fifteen-minute OxiClean™ sections. Similar results were found for acetylfentanyl. Notably, the researchers found that by the thirty-minute time point, all liquids had evaporated and the fentanyl and acetylfentanyl were not removed by the paper towel. The likely explanation is that the fentanyl had dissolved and was then distributed in a thin layer across the benchtop when the liquid evaporated, preventing removal by the towel. Based on these results, the authors recommend that fentanyl and acetylfentanyl be cleaned by spraying powders with enough 1% solution of OxiClean™ to cover the powder and then scrubbing with a paper towel within fifteen minutes. The authors concluded by warning that the spray will lose its cleaning ability once the liquid has evaporated, and that any paper towels used should be disposed of in a biohazard waste container.

Additional targeted searches of peer-reviewed literature returned two publications that similarly examine the efficacy of various cleaning solutions for environmental decontamination. Firstly, a study by Sisco et al. examined the effectiveness of OxiClean™ and Dahlgren Decon (also a peroxide solution) for removing cyclopropyl fentanyl and carfentanil from ceramic floor tiles.[43] Approximately 500 μg to 600 μg of either carfentanil or cyclopropyl fentanyl powder was deposited on the test surface, and then approximately 2mL of either OxiClean™ or Dahlgren Decon was pipetted to cover the powder and allowed to sit for between zero and thirty minutes before being wiped off. After wiping, the surface was swabbed and tested for residual intact carfentanil or cyclopropyl fentanyl by mass spectrometry (Thermal Desorption-Direct Analysis in Real Time Mass Spectrometry (TD-DART-MS) and Liquid Chromatography Tandem Mass Spectrometry (LCMS/MS)). Both cleaning agents were highly effective, with Dahlgren Decon removing over 99 percent of both cyclopropyl fentanyl and carfentanil within five minutes, and OxiClean™ removing over 99 percent of cyclopropyl fentanyl and approximately 97% of carfentanil within five minutes. However, some intact drug was detected on the surface and in the solution of both agents after cleaning, meaning that the solutions did not degrade or remove all of the opioid present. In addition, two cyclopropyl fentanyl samples treated with OxiClean™ were inadvertently allowed to evaporate, which, as in the Froelich study, lowered the removal efficacy. The authors reinforce the conclusion drawn by Froelich that drug removal is only achievable if the cleaning solution does not evaporate. A similar experiment testing the ability of methanol, Alconox detergent and water, and OxiClean™ to remove cyclopropyl fentanyl and heroin particulate matter from a laboratory benchtop found that all methods tested removed over 99% of cyclopropyl fentanyl particulate matter and more than 98% of heroin particulate matter. This result supports the EPA recommendation of using detergent and water for nonporous surfaces, though only one type of detergent was used, and these results may differ for other types of detergent or soaps.

In addition, the authors examined the ability of OxiClean™ and Dahlgren Decon to degrade cyclopropyl fentanyl and carfentanil in solution. Results indicated that OxiClean™ achieved breakdown of approximately 85% of cyclopropyl fentanyl and 95% of carfentanil after fifteen minutes. For Dahlgren Decon, both opioids were undetectable at all time points, corresponding with approximately 95% effectiveness for cyclopropyl fentanyl and a 97.6%

effectiveness for carfentanil. Together, these results indicate that both Dahlgren Decon and OxiClean™ are effective at decontaminating surfaces by removing or degrading cyclopropyl fentanyl and carfentanil, but that incomplete degradation may leave some amount of intact opioid residue behind.

Secondly, a 2009 study by Qi et al. examined the oxidative degradation of fentanyl in aqueous peroxide and hypochlorite solutions.[44] The peroxide solutions demonstrated a range of degradation efficiencies, with the two most efficient solutions, peracetic acid and sodium percarbonate/N,N,N',N'-tetraacetylethylene diamine (SPC/TAED), achieving more than 90% degradation within ten minutes. For the hypochlorite solutions, trichloroisocyanuric acid (TCCA) achieved 96% degradation within two minutes and complete degradation in sixty minutes. The high efficacy of peracetic acid supports the recommendation of its use by the EPA and IAB. Although the IAB also recommends hydrogen peroxide, Qi found hydrogen peroxide to be among the least efficient solutions, achieving a maximum of 53% degradation after sixty minutes. Notably, the authors found that calcium hypochlorite with a pH of 12, which is similar to household bleach (sodium hypochlorite, pH 12.5),[45] partitioned solid fentanyl out of the aqueous solution. The authors note that fentanyl has low solubility in strong basic solutions, making degradation inefficient. This result suggests that bleach and other strong basic solutions may all be similarly inefficient at dissolving and degrading fentanyl and are therefore not appropriate decontaminating agents, which supports the fact that none of the guidance documents recommend bleach for environmental decontamination.

Although the Qi study did not examine OxiClean™ or Dahlgren Decon specifically, their results nonetheless concur with the findings of Froelich and Sisco. OxiClean™ and Dahlgren Decon are both peroxide solutions—OxiClean™ contains sodium percarbonate (SPC) while Dahlgren Decon releases peracetic acid upon dissolution in water[46]—and Qi found both SPC and peracetic acid to be efficient degradants of fentanyl. Overall, results across the three studies indicate that certain peroxide and (nonalkaline) hypochlorite solutions can efficiently remove and destroy fentanyl and carfentanil and are therefore promising decontamination agents.

Decontamination knowledge and utilization.—Only one study was found that examines knowledge and utilization of decontamination methods. In the Persaud/Jennings 2019 survey of New York State law enforcement officers, firefighters, and EMS personnel (discussed above), 37% of EMS/firefighters and 24% of law enforcement officers answered that hand sanitizer is safe to use after handling fentanyl.[34] If alcohol-based hand sanitizer increases transdermal absorption, then the approximately onethird of first responders who believe hand sanitizer is safe to use may be at increased risk of harm. No other studies examining knowledge or utilization of decontamination methods were identified.

Opioid disposal.—The EPA recommends that fentanyl and its analogs be managed as hazardous waste. All fentanyl and fentanyl-containing materials should be placed in heavy-mil, leak-proof polyethylene containers, and should be disposed of by encapsulation, incineration, or inertization by mixing with water, cement, or limestone to form a solid mass.[39] Froelich et al. notes that the majority of law enforcement agencies do not have toxic waste containers or chemical waste treatment abilities, but often do have biohazard waste containers and disposal capabilities due to their frequent contact with body fluids.[42] The authors state that biohazard containers and the approved methods for disposal of biohazard materials, particularly incineration, should be sufficient for the disposal of opioids, which is confirmed by the EPA recommendations. However, hazardous waste disposal capabilities are likely limited for workplaces that do not regularly encounter chemical or biological waste.

Decontamination and disposal—Gaps.—For personal decontamination, little data are available to support the current recommendations, and the risks associated with alcohol and hand sanitizer use are not well understood. Although alcohol acts as a skin penetrant in a pharmaceutical context, it is unclear to what extent it may enable the dissolution and skin permeation of tablet or powder opioids (two possible illicit forms). Since hand sanitizer is widely available and may be used by responders as indicated in the Persaud-Jennings survey, an examination of the risks it may pose may potentially clarify the recommendations against its use. Furthermore, no studies have examined the removal of opioids from skin or equipment by any agent, including soap and water, and water also may facilitate permeation of the skin by opioids. Decontamination methods validated for surfaces or equipment may not be appropriate for personal decontamination because they are irritating or damaging to skin and body tissues. Targeted studies are needed to examine decontamination methods for people and PPE, and ideally these will consider environmental factors, ease of use, and human health consequences. As one of the main benefits of hand sanitizer is that it can be used in situations where access to running water is limited, future research should investigate best practices for cleaning contaminated skin with a focus on methods that can be used when handwashing is impractical.

For environmental decontamination, current research does lend support to existing recommendations and has revealed several promising cleaning agents. However, there are still very few studies examining environmental decontamination and there are clear gaps in research on several types of opioids and different field conditions. Neither of the studies examining degradation included opioids other than fentanyl or carfentanil. Opioids are structurally diverse and therefore may degrade with different kinetics under various conditions, and indeed the Sisco study notes that it is unclear why OxiClean™ was more effective at degrading carfentanil than cyclopropyl fentanyl. Ideally, research should include a variety of illicit opioids, both in pure form and mixed with other licit and illicit opioids, nonopioid drugs, and common adulterants to represent what workers may encounter. Further, complete degradation was not achieved by even the most promising cleaning solutions, and the conditions required to achieve this are unclear. A variety of chemical and environmental factors, which are not fully explored in the literature, likely affect opioid removal and degradation efficiencies (ratio of opioid to solution, solution concentration, solution pH, application method, timing, temperature, surfaces, etc.). Additional studies are needed to determine not only which substances can efficiently remove and/or degrade which opioids, but also what field conditions affect decontamination efficacy.

Moreover, research on environmental decontamination is complicated by the fact that there are no health-based guidelines on what percentage or mass of illicit opioid must be degraded or removed before an item or surface is deemed safe. There is at least one state legal limit for fentanyl residuals after remediation that defines nondetectable as the "safe" limit, though this is based on measurement sensitivity rather than health outcomes.[47] Total removal or degradation has not been achieved under laboratory conditions and is likely not a realistic standard for decontamination in the field. Determining appropriate clearance end points that consider differences in potency between opioids, the likelihood of various exposure routes, and realistic field conditions would greatly enable the study of decontamination methods.

The literature search revealed limited research on knowledge and compliance rates with recommended personal and environmental decontamination methods. If there are misconceptions about proper decontamination and disposal methods or noncompliance with recommendations, workers may be placing themselves and others at increased risk of exposure. Research is needed on whether workers in various occupations that may encounter opioids are familiar with and follow the existing guidelines, and compliance barriers. Similarly, studies such as the Persaud-Jennings survey could investigate the disposal capabilities and practices of various facilities, what barriers to proper disposal exist, and how various disposal methods increase or decrease the risk of occupational exposure.

Engineering controls for preventing illicit opioid exposure

Engineering controls for needlestick exposures—Peer-reviewed and gray literature.—The delivery of illicit opioids by injection poses a risk of occupational exposure through accidental NSIs, and sharps containers have long been identified as an appropriate engineering control for reducing this type of exposure.[48] Our literature search identified three publications that substantiate the occupational hazard of NSIs among police officers in the context of the opioid crisis; however, none of the studies directly validate the use of sharps containers to reduce opioid exposure.

An occupational safety study of Tijuana police personnel by Beletsky et al. found that only 1.5% of officers reported an NSI, but there was a statistically significant correlation between NSI frequency and the frequency of confiscating syringes from suspects, transporting syringes, breaking syringes, discarding syringes, and arresting a suspect for syringe possession.[49] A similar study by Cepeda et al. details the findings of a survey of more than 700 Baltimore city police officers evaluating police experience and sentiments on NSIs and protective behaviors.[50] Sixty officers (8% of respondents) indicated a lifetime NSI, for an NSI prevalence rate of fifty-eight occurrences per 10,000 officer-years. In addition, 95% of officers said that they would utilize needlestick resistant gloves if available, indicating a willingness of police to use appropriate protective measures.

The third study: a 2016 NIOSH HHE, provides additional insights into the prevalence of NSIs and recommendations to mitigate occupational risk.[48] The authors assessed an urban Ohio police department's NSI reports from 2011–2016 and found an annual NSI incidence rate of between 0 and 5.07 per 1000 police officers. Pat-down searches of a suspect and searches of a suspect's property or vehicle were found to increase risk. The authors identified one NSI that was caused by a sharp being left in an inappropriate place by an officer, but the records do not clarify if this incident was related to the nonuse or misuse of a sharps container or other type of engineering control. Significantly, evaluators noted that the police department was using a container made of heavy-duty fiberboard with a metal screw-on lid to store needles collected in the field, which is not compliant with current best practices. The evaluators recommended the use of sharps containers that are puncture resistant, leakproof, and labeled or color-coded and that officers be instructed in the prompt transfer of needles to appropriate sharps containers.

Engineering and administrative controls for powdered illicit opioids.—Our literature search returned no publications suggesting that portable receptacles or other systems to prevent the dissemination of powdered opioid hazards exist. Nor does it seem that the use of makeshift receptacles on-scene have been approved by federal, state, or local stakeholders. For instance, according to an authoritative 2017 DEA guidance resource,[9] law enforcement personnel should avoid any actions that may disturb loose powders and/or other drug-related evidence on-scene, and instead contact either officials within their agency trained in handling hazardous materials or the nearest DEA office. Concurrently, law enforcement personnel on-scene are required to don the appropriate PPE and standby for the arrival of trained personnel. Suspected opioid materials should be double-bagged within two agency-approved envelopes and transported within DOT-compliant, level 4G fiberboard boxes or “Pelican” style cases to appropriate laboratories for testing.[9] Currently, responders without special training or equipment are directed not to disturb or take field samples of packaged materials if fentanyl and fentanyl analogs are suspected as opening a package may suspend the powder and cause exposure.[39]

Jurisdictions have developed policies for handling evidence in laboratories, which are normally purpose-designed or retrofitted settings that are appointed with engineering controls such as ventilated chemical hoods. One HHE-evaluated drug exposure among forensic scientists who analyzed evidence for the presence of illicit drugs.[35] In this HHE, the forensic laboratories visited had several ventilated chemical hoods that did not meet expected performance criteria and unknown powders were regularly handled on the benchtop without use of available local exhaust ventilation nor a ventilated chemical hood. Evaluators recommended the adoption of additional administrative controls: policies to limit handling of uncontained unknown powered, such as limiting the measurement of material net weights unless required by legal proceedings and more specific instructions for employees on when to use ventilated enclosures.

For control of another workplace exposure, mail handling guidance for anthrax bacteria recommends immediately covering the package and its spilled contents with items nearby (e.g., dustbin, paper, plastic bag).[51] This process may indeed mitigate further exposure to opioids. However, we found no studies examining the efficacy of such ad-hoc measures as well as no commercial systems that could be employed for this express purpose. The only somewhat similar item found was portable mail screening equipment consisting of a portable glove-box with HEPA-filtered exhaust air, which has been developed to prevent anthrax exposure when opening packages.[52] Similar systems could be employed to safely open packages suspected of containing powdered opioids.

Engineering and administrative controls—Gaps.—No studies were found examining the utility of engineering controls for reducing occupational opioid exposure. The studies on NSI among police[49,50] validate the risk and need for protection, and the HHE[48] reiterates the recommendation of using a sharps container, but no studies were found directly addressing the utilization of sharps containers or other engineering controls for reducing NSI. The finding that a police department was not using sharps containers compliant with current recommendations suggests that other departments may be similarly using unsuitable engineering controls for potentially drug-contaminated needles, and additional research may reveal whether and how these improper engineering controls contribute to exposure risk. In addition, research on other workplaces is needed to understand the controls in place for nonresponder occupations. For example, research on bloodborne pathogen exposure has shown that NSIs may occur in the course of routine cleaning duties in hotels, restaurants, and gas stations.[53] Notably, the three studies detailed here do not represent the totality of literature on NSIs, as research framed solely in the context of preventing bloodborne pathogen transmission was not returned by our literature search. Further examination of the literature on engineering controls for preventing accidental bloodborne infection may yield useful lessons for preventing occupational opioid exposure. Similar to needlesticks and bloodborne pathogens, research on controls for powdered opioids could be informed by research on other solid threat agents that carry additional risk when aerosolized, particularly anthrax, though we found no mention of controls for anthrax currently in use.

Administrative controls impact occupational exposure to illicit opioids directly and indirectly, such as by mandating how and when engineering controls and PPE are used and how to handle uncontained, unknown powders. The findings in the drug laboratory HHE suggest that engineering controls should be paired with appropriate administrative policies, employee training, and maintenance procedures to be effective.[35] The literature search revealed that minimal research is available on both how administrative controls should be implemented and their effectiveness at reducing illicit opioid exposures when they are in place.

Discussion: Research Gaps Related to Protecting Against Occupational Opioid Exposure

The research gaps concerning protection against illicit opioid exposures are two-fold: gaps in technical knowledge about PPE, decontamination, and control methods, and gaps in understanding how these measures are utilized. Sufficient protection is a combination of both technical quality and proper use, and additional studies are needed to understand and overcome barriers in both.

Little is known about the knowledge levels, attitudes, and practices of first responders and other workers in terms of PPE utilization and personal decontamination. The little research that does exist on this topic suggests that responder behavior does not always align with recommendations, likely placing workers at increased risk of exposure. Additional research is needed to understand these behaviors, and to understand how employers' administrative policies, organizational culture, trainings, and compliance with existing PPE standards and regulations can better facilitate safe work practices. Surveys such as those utilized by Persaud/Jennings and the NIOSH HHEs are promising tools for examining employer and worker knowledge and practices and could be used to collect data across a variety of occupations and locations. Additional ethnographic methods, such as on-site observation and informative interviews, could also yield important data on how protective measures are employed in the field, the unique needs of various occupations, and possible approaches to decrease occupational exposure risk.

In terms of technical performance, limited publicly available data exist on the efficacy of PPE, decontamination methods, and engineering controls against illicit opioids. Assumptions about PPE, decontamination, and engineering control efficacy are informed by knowledge within NIOSH from other contexts, and future research on these topics may even benefit from existing data on the efficacy of PPE and controls for similar hazards, such as anthrax, bloodborne infectious agents, or pharmaceutical analgesics. However, data from other contexts must be validated against the unique threat posed by highly potent illicit opioids. Studies that examine the efficacy of protective measures and decontamination for the evolving forms of illicit opioids encountered on the street, within the unique environments in which responders and other workers operate, and accounting for the unique stresses placed on equipment during an emergency scenario are almost nonexistent. For decontamination, the degradation mechanisms of many opioids are not well understood, and there are no established clearance goals to guide the determination of decontamination efficacy.

Addressing these gaps would not only improve the safety recommendations for preventing occupational exposure to illicit opioids, but also help assuage the fear and misconceptions surrounding illicit opioids. The ACMT/AACT concludes that existing evidence indicates that absorption from small, unintentional skin exposures is unlikely to cause significant opioid toxicity, and if it were to occur, would develop slowly and allow time for proper decontamination.[10] Others have similarly noted that existing pharmacokinetic and clinical data do not suggest a great danger from ambient dermal exposure and that anecdotal reports of occupational opioid poisoning do not accurately reflect risk.[4,5] However, these authors nonetheless conclude that until more information is available, the use of PPE is prudent and important because dermal exposure and incidental transfer from the skin to mucous membranes are an important potential route of exposure. Thus, information on exposure routes, protective measures, and decontamination would allow workers to complete their duties with a more accurate understanding of the risks they face and the measures in place to protect their health.

In addition, while first responders may face a unique threat of occupational exposure to illicit opioids, they are not alone in potentially needing protection. Educational staff, hotel staff, airline flight crews, public transit workers, librarians, food service workers, and many others may encounter illicit opioids and drug paraphernalia.[1,2] Overall, increasing our knowledge of how to protect against exposure to illicit opioids has the potential to improve occupational health across communities. However, as the illicit opioid landscape changes, these research questions must continue to be revisited for any novel opioid derivatives to ensure that our understanding of appropriate protection remains accurate.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This publication was supported by the National Institute for Occupational Safety and Health under award number URSFS62012.

Biographies

Author Biographies Casey Basham is a senior analyst at Gryphon Scientific with a background in biology. Her work has included the development of policy resources and training materials to improve global health, biosecurity, and outbreak response capabilities.

Audrey Cerles, MS, is a microbiologist with expertise supporting risk assessments in various fields, including emerging infectious diseases and emerging biotechnologies. Cerles holds a BA in microbiology from Cornell University and an MS in food safety and defense from Michigan State University, where she conducted research into food additive contamination. Since joining Gryphon Scientific in 2013, Cerles has also worked on developing various training programs related to insider threat awareness and first responder safety.

Margaret Rush is an infectious disease biologist whose career has focused on helping clients harness the power of their scientific data to answer critical research questions in public health, with a focus on global health. Rush developed her analytics expertise while completing her PhD at Harvard focused on malaria drug discovery. After graduation in 2009, she joined Gryphon Scientific where she is a partner and leads projects to collect, curate, analyze, and model complex data for clients including CDC, USAID, FEMA, DOD, and NIH. Her training in biological sciences for public health and expertise in data science is complimented by a strong background in training on health and emergency preparedness.

Marissa Alexander-Scott, DVM, MS, MPH, is a researcher in the Health Effects Laboratory Division; Assistant Coordinator for the Immune, Infectious, and Dermal Cross-Sector; and the Opioid Research Gap Co-Team Lead at the National Institute for Occupational Safety and Health (NIOSH). She holds degrees in Veterinary Medicine, Forensic Toxicology, and Environmental Public Health (Epidemiology). Although her research interests have led her to methods development and exposure assessment projects with Healthcare, Oil and Gas, Construction, and Public Safety Workers, she continues to practice preventative veterinary medicine care to support One Health initiatives as well.

Lee Greenawald is a Physical Scientist with the National Personal Protective Technology Laboratory of the National Institute for Occupational Safety and Health (NIOSH). Lee received her BS in Forensic Chemistry from Ohio University and a PhD in Analytical Chemistry from West Virginia University. Lee has conducted post-market research to evaluate the performance of different types of personal protective equipment after long-term storage or against CBRN hazards, and in her current role is part of various respirator research and certification activities as part of NIOSH’s Respirator Approval Program.

Sophia Chiu is an occupational medicine physician. She works as a medical officer in the Health Hazard Evaluation program at the National Institute for Occupational Safety and Health. She has degrees in statistics, philosophy, and public health.

Kendra Broadwater has been an industrial hygienist with the NIOSH Health Hazard Evaluation Program since 2013. She received her MPH degree from the University of Michigan and her BS degree from the University of Washington. She has performed illicit drug exposure assessments for employees who work in forensic laboratories.

Deborah Hirst, PhD, PE, is the Deputy Branch Chief with the Division of Field Studies and Engineering, Engineering and Physical Hazards Branch in Cincinnati, Ohio. Hirst holds a Bachelor of Science degree in civil and environmental engineering and a doctorate in environmental health engineering from the University of Alabama at Birmingham. Hirst has researched and evaluated engineering control technology on hazardous occupational air contaminants including: diacetyl and other flavorings, formaldehyde, 1-bromopropane (1-BP), indium-tin oxide, and hazardous drugs.

John Snawder received his PhD degree from Mississippi State University in 1990 and did post-doctoral work in the National Center for Toxicological Research. He has been a Diplomate of the American Board of Toxicology since 1995 and served on its Board of Directors from 2008 to 2012. From 1992–present, he has worked at NIOSH as a research toxicologist. Snawder is the co-director of the NIOSH Center for Direct Reading and Sensor Technology and is the leader of the Biological Monitoring Research Team.

Jennifer Roberts is a Research Chemist with the Health Effects Laboratory Division (HELD) of the National Institute for Occupational Safety and Health (NIOSH). She received her B.S. in Chemistry from Xavier University in Cincinnati. Jennifer currently serves as the Laboratory Coordinator for the Chemical and Biological Monitoring Branch of HELD and as the Project Officer for the Institute's Comprehensive Analytical Chemistry Support Contract.

Angela Weber is the program coordinator of the NIOSH Disaster Science Responder Research Program in the Emergency Preparedness and Response Office. Over the last 25 years, she has been a part of the federal response to a variety of natural and man-made disasters and infectious disease events, as well as efforts to plan and conduct emergency exercises. She has led and participated in the evaluation of hazards identified as part of disaster responses including SARS, multiple anthrax and ricin incidents, hurricanes, Ebola, and COVID-19. She received her MS in Environmental Science and Occupational Health from the University of Cincinnati.

Martha Knuth, MLIS, is a librarian at the Stephen B. Thacker CDC Library. She came to CDC after working in a variety of hospital, academic, and medical libraries. She loves helping fulfill the Stephen B Thacker CDC library's mission of advancing science, health, and medicine through information in order to protect the health, safety, and security of the public.

Rocco Casagrande trained as a biochemist. Casagrande has spent his career combining deep scientific expertise with novel methodologies to tackle the most daunting threats facing the nation. He has led more than 50 projects to reduce the threat posed by weapons of mass destruction by guiding government investments in medicines, detection systems, and interdiction platforms. He has analyzed avenues for the possible misuse of advanced biotechnology and recommended means to reduce this risk without hampering scientific or industrial progress.

References

1. Wolfson-Stofko B, Bennett AS, Elliott L, et al. Drug use in business bathrooms: an exploratory study of manager encounters in New York City. Int J Drug Policy 2017; 39: 69–77. [PubMed: 27768996]
2. Thomas AR and Schwartz RM. At-risk populations to unintentional and intentional fentanyl and fentanyl+ exposure. J Transp Secur 2019; 12: 73–82.
3. U.S. Department of Homeland Security. Proceedings from the 2017 Fentanyl Working Meeting: Protecting first responders on the frontlines of the fentanyl epidemic. Washington, DC: U.S. Department of Homeland Security, 2018.
4. Cole JB and Nelson LS. Controversies and carfentanil: we have much to learn about the present state of opioid poisoning. Am J Emerg Med 2017; 35: 1743–1745. [PubMed: 28851500]
5. Lynch MJ, Suyama J and Guyette FX. Scene safety and force protection in the era of ultra-potent opioids. Prehosp Emerg Care 2018; 22: 157–162. [PubMed: 28956680]
6. Howard J and Hornsby-Myers J. Fentanyls and the safety of first responders: science and recommendations. Am J Ind Med 2018; 61: 633–639.
7. Leen JLS and Juurlink DN. Carfentanil: a narrative review of its pharmacology and public health concerns. Can J Anaesth 2019; 66: 414–421. [PubMed: 30666589]
8. NIOSH. Fentanyl: preventing occupational exposure to emergency responders, https://stacks.cdc.gov/view/cdc/52812 (2017, accessed 6 August 2021).
9. Drug Enforcement Administration. Fentanyl: a briefing guide for first responders. Springfield, VA: Drug Enforcement Administration, 2017.
10. Moss MJ, Warrick BJ, Nelson LS, et al. ACMT and AACT position statement: preventing occupational fentanyl and fentanyl analog exposure to emergency responders. J Med Toxicol 2017; 13: 347–351. [PubMed: 28842825]
11. The InterAgency Board. 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, 2017.
12. Holt PJ. Particle size analysis of six illicit heroin preparations seized in the U.K. Forensic Sci Int 1996; 81: 17–28.
13. Rook EJ, Huitema AD, Ree JMV, et al. Pharmacokinetics and pharmacokinetic variability of heroin and its metabolites: review of the literature. Curr Clin Pharmacol 2006; 1: 109–118. [PubMed: 18666382]
14. Respirator trusted-source information section 1: NIOSH-approved respirators, www.cdc.gov/niosh/npptl/topics/respirators/disp_part/respsource1quest2.html (2020, accessed 15 July 2021).
15. Mostofi R, Wang B, Haghighat F, et al. Performance of mechanical filters and respirators for capturing nanoparticles-limitations and future direction. Ind Health 2010; 48: 296–304. [PubMed: 20562505]
16. Greenawald LA, Karwacki CJ, Palya F, et al. Conducting an evaluation of CBRN canister protection capabilities against emerging chemical and radiological hazards. J Occup Environ Hyg 2020; 17: 480–494. [PubMed: 32776823]
17. Yadav S, Swami D, Kumar P, et al. Acute inhalation toxicity of smoke of fentanyl and its 1-substituted analogs in Swiss albino mice. Cell Mol Biol (Noisy-le-Grand, France) 2014; 60: 1–9.

18. Macleod DB, Habib AS, Ikeda K, et al. Inhaled fentanyl aerosol in healthy volunteers: pharmacokinetics and pharmacodynamics. Anesth Analg 2012; 115: 1071–1077. [PubMed: 22984155]
19. Qian Y, Willeke K, Grinshpun SA, et al. Performance of N95 respirators: filtration efficiency for airborne microbial and inert particles. Am Ind Hyg Assoc J 1998; 59: 128–132. [PubMed: 9487666]
20. Rengasamy S, Eimer BC and Shaffer RE. Comparison of nanoparticle filtration performance of NIOSH-approved and CE-marked particulate filtering facepiece respirators. Ann Occup Hyg 2009; 53: 117–128. [PubMed: 19261695]
21. Brosseau L and Berry Ann R. N95 respirators and surgical masks, https://blogs.cdc.gov/niosh-science-blog/2009/10/14/n95/ (2009, accessed 6 August 2021).
22. Mansouri M, Tidley M, Asanati K, et al. Comparison of blood transmission through latex and nitrile glove materials. Occup Med (Lond) 2010; 60: 205–210. [PubMed: 20097745]
23. Patel HB, Fleming GJ and Burke FJ. Puncture resistance and stiffness of nitrile and latex dental examination gloves. Br Dent J 2004; 196: 695–700. [PubMed: 15192735]
24. Greenawald LA, Hofacre KC and Fisher EM. Fentanyl and carfentanil permeation through commercial disposable gloves. J Occup Environ Hyg 2020; 17: 398–407. [PubMed: 32658631]
25. FENTANYL: incapacitating agent, https://www.cdc.gov/niosh/ershdb/emergencyresponsecard_29750022.html (2020, accessed 2 March 2020).
26. Andreae MH, Rhodes E, Bourgoise T, et al. An ethical exploration of barriers to research on controlled drugs. Am J Bioeth 2016; 16: 36–47.
27. Nutt D Illegal drugs laws: clearing a 50-year-old obstacle to research. PLoS Biol 2015; 13: e1002047. [PubMed: 25625189]
28. Drug scheduling, https://www.dea.gov/drug-scheduling (2020, accessed 24 March 2020).
29. Meeting with NIOSH Opioids Research Workgroup, 19 February 2020.
30. Chiu S, Wiegand DM, Broadwater K, et al. Interim report: evaluation of occupational exposures to opioids, mental health symptoms, exposure to traumatic events, and job stress in a city fire department. Washington, DC: National Institute for Occupational Safety and Health, Health Hazard Evaluation Program, 2019.
31. Chiu S, Hornsby-Myers J and Trout D. HHE Report No. 2018–0132-3322: evaluation of a New Hampshire law enforcement officer’s unintentional occupational exposure to illicit drugs. Washington, DC: National Institute for Occupational Safety and Health, Health Hazard Evaluation Program, 2018.
32. Jackson D, Chiu S and Hornsby-Myers J. HHE Report No. 2018–0118-3331: evaluation of law enforcement officers’ potential occupational exposure to illicit drugs. Washington, DC: National Institute for Occupational Safety and Health, Health Hazard Evaluation Program, 2018.
33. Chiu S, Hornsby-Myers J and Trout D. HHE Report No. 2018–0083-3332: evaluation of occupational exposures to illicit drugs during a law enforcement and emergency medical services response. Washington, DC: National Institute for Occupational Safety and Health, Health Hazard Evaluation Program, 2018.
34. Persaud E and Jennings CR. Pilot study on risk perceptions and knowledge of fentanyl exposure among New York state first responders. Disaster Med Public Health Prep 2019; 14: 437–441. [PubMed: 31571559]
35. Broadwater KR, Jackson DA and Li JF. HHE Report No. 2018–0090-3366: evaluation of occupational exposures to illicit drugs at controlled substances laboratories. Washington, DC: National Institute for Occupational Safety and Health, Health Hazard Evaluation Program, 2020.
36. Maglio MA, Scott C, Davis AL, et al. Situational pressures that influence firefighters’ decision making about personal protective equipment: a qualitative analysis. Am J Health Behav 2016; 40: 555–567. [PubMed: 27561858]
37. Kahn SA, Leonard C, Lee YG, et al. A pilot survey of Southeastern firefighters: safety practices, use of protective gear, and injury. Burns 2020; 46: 298–302. [PubMed: 31780278]
38. Moore SM. NIOSH efforts to learn about firefighter personal protective equipment (PPE). Urban Fire Forum. Webinar Presented on 8 October 2020.

39. Environmental Protection Agency U.S. Fact sheet for OSCs: fentanyl and fentanyl analogs, Version 1.0 Washington, DC: U.S. Environmental Protection Agency, 2018.
40. Lehmann KA and Zech D. Transdermal fentanyl: clinical pharmacology. J Pain Symptom Manage 1992; 7: S8–S16. [PubMed: 1517637]
41. Lent EM, Maistros KJ and Oyler JM. In vitro dermal absorption of carfentanil. Toxicol In Vitro 2020; 62: 104696. [PubMed: 31669393]
42. Froelich NM, Sprague JE and Worst TJ. Letter to the editor-elbow grease and OxiClean™ for cleaning fentanyl- and acetylfentanyl-contaminated surfaces. J Forensic Sci 2018; 63: 336–338. [PubMed: 29314013]
43. Sisco E, Najarro M and Burns A. Quantifying the effectiveness of cleaning agents at removing drugs from laboratory benches and floor tiles. Forensic Chem 2019; 12: 1–7.
44. Qi L, Cheng Z, Zuo G, et al. Oxidative degradation of fentanyl in aqueous solutions of peroxides and hypochlorites. Defence Sci J 2011; 61: 30–35.
45. The Clorox Company. Safety data sheet: Clorox bleach cleaner. Oakland, CA: The Clorox Company, 2014.
46. Decon Dahlgren, www.cbrnetechindex.com/p/4605/First-Line-Technology-LLC/Dahlgren-Decon (accessed 2 April 2020).
47. California State Assembly Bill AB-1596 Hazardous substances: contaminated property: fentanyl cleanup, 2019.
48. de Perio MA. HHE Report No. 2016–0121-3284: evaluation of needlestick injuries and other exposures to bloodborne pathogens among officers in a city police department. Washington, DC: National Institute for Occupational Safety and Health, Health Hazard Evaluation Program, 2017.
49. Beletsky L, Abramovitz D, Arredondo J, et al. Addressing police occupational safety during an opioid crisis: the syringe threat and injury correlates (STIC) score. J Occup Environ Med 2020; 62: 46–51. [PubMed: 31658223]
50. Cepeda JA, Beletsky L, Sawyer A, et al. Occupational safety in the age of the opioid crisis: needle stick injury among Baltimore police. J Urban Health 2017; 94: 100–103. [PubMed: 28105586]
51. U.S. Department of Homeland Security. Best practices for safe mail handling. Washington, DC: U.S. Department of Homeland Security: Interagency Security Committee, Department of Homeland Security, 2010.
52. Lohmann E Anthrax-safe box creates stir. Wired, 25 October 2001, www.wired.com/2001/10/anthrax-safe-box-creates-stir/
53. Chen GX and Jenkins EL. Potential work-related exposures to bloodborne pathogens by industry and occupation in the United States Part II: a telephone interview study. Am J Ind Med 2007; 50: 285–292. [PubMed: 17340611]

Table 1.

Summary of PPE Recommendations.

PPE category	Primary function	Recommended items	Recommended by
Respirators	Prevent inhalation of aerosolized opioid particles[b]	Fitted N95 respirator N100, R100, or P100 filtering facepiece respirator or elastomeric half mask respirator with N100, R100, or P100 filters. Self-contained breathing apparatus Powered air-purifying respirator with high-efficiency particulate air filter CBRN full facepiece air-purifying respirator	DEA, ACMT/AACT NIOSH, ACMT/AACT NIOSH, DEA, IAB NIOSH, DEA, IAB IAB
Gloves	Protection against dermal exposure of the hands	Nitrile gloves certified to NFPA 1999(single-use examination gloves)	NIOSH, DEA, ACMT/AACT, IAB
Eye protection	Protection against ocular exposure to aerosolized powders or liquids or touching of the eye with contaminated hands	Safety glasses/any OSHA-approved eye protection Nonvented or indirect vented goggles, full-face respirator	NIOSH, DEA, ACMT/AACT, IAB IAB
Garment-type protectors	Protection against dermal exposure of the body	Chemical resistant or particulate hazards protective ensemble Sleeve covers Water resistant coveralls Booties/shoe covers/protective footwear	NIOSH, DEA, IAB NIOSH ACMT/AACT DEA, IAB

EPA = U.S. Environmental Protection Agency; NIOSH = National Institute for Occupational Safety and Health; DEA = U.S. Department of Justice Drug Enforcement Administration; IAB =InterAgency Board for Emergency Preparedness and Response; ACMT/AACT =American College of Medical Toxicology and the American Academy of Clinical Toxicology; CBRN = NIOSH-approved chemical, biological, radiological, nuclear; OSHA = Occupational Safety and Health Administration; NFPA = National Fire Protection Association.

Author Manuscript

Author Manuscript

Author Manuscript

[b.]Recommended respiratory protection is based on exposure level.

Table 2.

Summary of Decontamination Recommendations.

Decontamination method	Decontamination target	Recommended?	Sources
Water and soap/detergent	Personal, PPE	Yes	EPA,[39] NIOSH,[8] DEA,[9] IAB[11]
	Environment	Yes, for nonporous surfaces	EPA
Hydrogen peroxide	PPE, Environment	Yes	IAB
Peracetic acid, Dichloroisocyanuric acid, Trichloroisocyanuric acid	Environment Personal, PPE	Yes No	EPA, IAB IAB
Alcohol-based sanitizers (hand sanitizers)	Personal	No	EPA, NIOSH, DEA, ACMT/AACT,[10] IAB
Bleach	Personal, PPE	No	NIOSH, IAB

PPE = personal protective equipment; EPA = U.S. Environmental Protection Agency; NIOSH = National Institute for Occupational Safety and Health; DEA = U.S. Department of Justice Drug Enforcement Administration; IAB = InterAgency Board for Emergency Preparedness and Response; ACMT/AACT = American College of Medical Toxicology and the American Academy of Clinical Toxicology.