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Standard Guide for Using Equipment and Assays for Field Detection of Fentanyl and Fentanyl-Related Compounds[1]

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1. Scope

1.1 This guide provides end-users and practitioners with information on the optimal use and limitations of assays and instrumentation designed to detect fentanyl and fentanyl-related compounds.

1.2 This guide also provides summaries and links to guidance documents on training, personal protective equipment (PPE), sampling and detection, and medical countermeasures.

1.3 This guide is intended for first responders and other end-users of field detection assays or instruments used to detect fentanyl and fentanyl-related compounds while out in the field. These instruments could also be used in a laboratory setting.

1.4 End-users will need to determine specific requirements including, but not limited to, use by hazardous material (HAZMAT) teams, use in explosive or other hazardous environments or atmospheres, use with PPE, use by firefighters or law enforcement officers, special electromagnetic compatibility needs, extended storage periods, and extended mission times. These specific requirements may or may not be generally applicable to all chemical detection systems.

1.5 *Units:*

1.5.1 The metric system is used for all measures of weight. All temperatures are given in °C.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E2771 Terminology for Homeland Security Applications

E3131 Specification for Nucleic Acid-Based Systems for Bacterial Pathogen Screening of Suspicious Visible Powders

E3243 Specification for Field Detection Equipment and Assays Used for Fentanyl and Fentanyl-Related Compounds

E3290 Test Method for Establishing Performance of Equipment and Assays for Field Detection of Fentanyl and Fentanyl-Related Compounds

2.2 *NFPA Standards:*[3]

NFPA 472 Standard for Competence of Responders to Hazardous Materials/Weapons of Mass Destruction Incidents

NFPA 473 Standard for Competencies for EMS Personnel Responding to Hazardous Materials/Weapons of Mass Destruction Incidents

NFPA 704 Standard System for the Identification of the Hazards of Materials for Emergency Response

2.3 *OSHA Standards:*[4]

29 CFR 1910.120 OSHA Hazardous waste operations and emergency response

29 CFR 1910.132 OSHA PPE Standard

29 CFR 1910.134 OSHA Respiratory Protection Standard

2.4 *Other Standards:*

Eurachem/CITAC Guide CG 4:2012 Quantifying Uncertainty in Analytical Measurement[5]

ISO 17034 General requirements for the competence of reference material producers[6]

[1] This guide is under the jurisdiction of ASTM Committee E54 on Homeland Security Applications and is the direct responsibility of Subcommittee E54.01 on CBRNE Detection and Decontamination.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02169-7471, http://www.nfpa.org.

[4] Available from Occupational Safety and Health Administration (OSHA), 200 Constitution Ave., NW, Washington, DC 20210, http://www.osha.gov.

[5] Available from Eurachem, https://www.eurachem.org/index.php.

[6] Available from International Organization for Standardization (ISO), ISO Central Secretariat, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, https://www.iso.org.

3. Terminology

3.1 *Definitions:*

3.1.1 *accuracy, n*—closeness of agreement between a test result and the accepted reference value. **E2771**

3.1.2 *assay, n*—quantitative or qualitative test used to determine the presence or absence of a target chemical compound.

3.1.2.1 *Discussion*—This definition differs slightly from Specification E3131; here it refers to chemical, and not necessarily biological materials or compounds.

3.1.3 *bulk sample, n*—total sample amount (including the sum of target and non-target compounds) that is visible to the naked eye; the amount of sample available for testing bulk samples according to this standard is >1 µg, but ≤10 mg.

3.1.4 *compound, n*—chemical substance under evaluation in this specification.

3.1.5 *false negative, n*—failure to detect a compound within a sample when it is present.

3.1.6 *false positive, n*—detection of a compound within a sample when it is not present.

3.1.7 *measurement process, n*—step, or series of systematic steps, used to detect a material or determine if a system or instrument performs as intended.

3.1.8 *non-target compound, n*—a compound other than the desired compound of interest to be detected; for fentanyl and fentanyl-related substances, this includes diluents/cutting agents, dyes/colorants, and other drugs that are not fentanyl or fentanyl-related substances.

3.1.8.1 *Discussion*—Non-target compounds should not give a positive test result for fentanyl or fentanyl-related substances (or another desired compound of interest to be detected); this is considered a false-positive result. Ideally, all non-target compounds should result in negative detection results for fentanyl and fentanyl-related compounds.

3.1.9 *operator, n*—person operating an on-site chemical assessment technology.

3.1.9.1 *Discussion*—This definition differs slightly from that in Specification E3131 as it applies to the chemical detection technology referred to in this document.

3.1.10 *precursor, n*—a chemical compound that is used in the synthesis of, generally, a compound with more complex chemical structure; in this guide, a precursor is a compound used to synthesize fentanyl and fentanyl-related compounds.

3.1.11 *reach-back support, n*—reach-back support refers to a service, often available 24 h a day/7 days per week via paid subscription through an equipment (instrument or assay) manufacturer; the service allows equipment users in the field to be in real-time contact with subject matter experts (SMEs) to provide advice and assessment of analysis results, including, but not limited to identification of one or more substances in an unknown sample.

3.1.11.1 *Discussion*—As an example, a field chemical detection instrument like a Raman spectrometer may be used to scan an unknown sample suspected of containing fentanyl or fentanyl-related compounds. The user can send the resulting data to reach-back support for review, interpretation, or both. The SMEs providing the support can identify poor-quality data and recommend settings for a successful rescan, perform advanced data analysis techniques to identify chemicals present in the sample, and quickly provide decision-support capabilities and guidance in response to end-user inquiries. Reach-back services are commonly used for aiding in the interpretation of ambiguous data and for confirmation of positive results (especially those with which decisions of consequence may be taken).

3.1.12 *reference material, n*—substance sufficiently homogenous and stable with respect to one or more specified properties that has been established to be fit for its intended use in the measurement process; properties can be quantitative or qualitative. **ISO 17034**

3.1.13 *saturation, n*—condition in which the detector response no longer increases with increased sample concentration.

3.1.13.1 *Discussion*—This can occur when there is too much sample introduced to an instrument or assay. For optical detection instruments, too much exposure to light, including ambient light, can saturate the detector.

3.1.14 *sensitivity, n*—change in the response of a measuring instrument divided by the corresponding change in the stimulus. **Eurachem/CITAC Guide CG 4:2012**

3.1.15 *specificity/selectivity, n*—ability of a measurement process to determine accurately and specifically the analyte of interest in the presence of other components in the sample matrix under the stated conditions of the test. **Eurachem/CITAC Guide CG 4:2012**

3.1.16 *target compound, n*—the compound of interest to be detected; for this guide it is fentanyl and fentanyl-related compounds.

3.1.16.1 *Discussion*—Ideally, all target compounds should result in positive detection results.

3.2 *Acronyms:*

3.2.1 *ATR*—attenuated total reflectance.

3.2.2 *CDC*—Centers for Disease Control.

3.2.3 *CFR*—Code of Federal Regulations.

3.2.4 *CONOPS*—concept of operations.

3.2.5 *DEA*—Drug Enforcement Agency.

3.2.6 *DOJ*—Department of Justice.

3.2.7 *EMS*—emergency medical services.

3.2.8 *EMT*—emergency medical technician.

3.2.9 *FEMA*—Federal Emergency Management Agency.

3.2.10 *FTIR*—Fourier transform infrared (also known as FTIR spectroscopy).

3.2.11 *GC*—gas chromatography.

3.2.12 *GC/MS*—gas chromatography/mass spectrometry.

3.2.13 *HAZMAT*—hazardous material team.

3.2.14 *HPMS*—high pressure mass spectrometry.

3.2.15 *IAB*—InterAgency Board.

3.2.16 *IMS*—ion mobility spectrometry.

3.2.17 *ISO*—International Organization for Standardization.

3.2.18 *MS*—mass spectrometry.

3.2.19 *NFPA*—National Fire Protection Association.

3.2.20 *NIOSH*—National Institute for Occupational Safety and Health.

3.2.21 *OSHA*—Occupational Safety and Health Administration.

3.2.22 *PPE*—personal protective equipment.

3.2.23 *SERS*—surface enhanced Raman spectroscopy.

3.2.24 *SME*—subject matter expert.

3.2.25 *TICs*—toxic industrial chemicals.

3.2.26 *TIMs*—toxic industrial materials.

3.2.27 *TLC*—thin layer chromatography.

3.2.28 *US&R*—Urban Search & Rescue (which may be FEMA or State teams).

4. Summary of Guide

4.1 This guide provides important information to end-users of field detection equipment and assays for safe collection and optimal testing of samples suspected of containing fentanyl and fentanyl-related compounds while out in the field. These instruments could also be used in a laboratory setting.

4.2 Information from this guide can be incorporated into planning, policy, training, and overall concept of operations (CONOPS) for responding to a scene where fentanyl or fentanyl-related compounds may be present. This guide recommends best practices and use and limitations of various field detection instruments and assays. Overview guidance and references are also given regarding sampling, PPE, decontamination, and medical countermeasures.

4.3 *Companion Standards*—While this guide is intended for emergency responders and those using field detection equipment or assays for measuring samples that are suspected of containing fentanyl while out in the field, two related companion standards that are technical in nature exist that were written for laboratory personnel who will be conducting performance testing of these types of instruments and assays in a laboratory setting. Specification E3243 defines the composition and amount of material to be used as test samples, as well as a statistically-based approach for defining performance. Test Method E3290 defines detailed protocols for preparing test samples and measuring them on different instruments and with different assays.

5. Significance and Use

5.1 This guide includes a wide range of technologies that are currently in use. Considerations and guidance for using these technologies are listed in each technology section.

5.2 The guide was compiled with significant input, review, and feedback from first responders; assay and instrument manufacturers; and local, state, and federal SMEs.

6. Summary of Existing Guidance Documents and Resources for Emergency Responders

6.1 The documents and guidance summarized below do not purport to address all hazards or best practices. They are provided here for reference and are not part of this standard's specific guidance.

6.2 *Training Guidance (**1**, **2**, **3**)*[7]

6.2.1 Responders should be trained on the potential hazards they might encounter and the necessary knowledge and skills to perform their work with minimal risk to their own safety and health, and that of other responders.

6.2.2 Responders who perform jobs where fentanyl or its analogues are reasonably anticipated to be present should also receive special training in conducting an on-scene risk assessment related to fentanyl and its analogues, and demonstrate an understanding of the following:

6.2.2.1 When to use PPE; what PPE is necessary; how to properly don, operate in, decontaminate, doff, dispose of, and maintain PPE; and the limitations of PPE.

6.2.2.2 What the potential exposure routes are for fentanyl and its analogues.

6.2.2.3 How to recognize the signs and symptoms of fentanyl and fentanyl-related substance exposure.

6.2.2.4 When and how to seek medical help.

6.2.3 Always comply with OSHA's hazardous materials standard (29 CFR 1910.120) involving hazardous substances (**1**, **3**).

6.3 *Safe Operating Procedures Guidance (**1**, **2**, **3**)*—Response personnel must balance safety with mobility and efficiency when working at scenes where fentanyl is known or suspected to be present. The first determination should be whether detection and identification of the material will change the response. If the answer is no, then strong consideration should be given to not interacting with the threat material for detection purposes, and instead packaging and providing it to law enforcement for laboratory testing with appropriate PPE and advanced detection equipment. If detection and identification of fentanyl is critical to the incident response, an incident-specific plan should be developed to perform the field testing in accordance with agency policies and procedures.

6.3.1 As with all first responder operations involving hazardous materials, responders should follow established safe work practices when fentanyl or its analogues are known or suspected to be present. Refer to reference documents for safe handling guidance to minimize risk of exposure.

6.3.2 Avoid performing tasks or operations that may aerosolize fentanyl due to increased exposure risks. Activities that aerosolize fentanyl require higher levels of PPE and should be conducted by appropriately trained personnel, and in accordance with agency policies and procedures.

6.3.3 Refer to reference documents for guidance on how to avoid exposure or cross-contamination.

6.4 *Detection Recommendations (**2**, **3**, **4**)*

[7] The boldface numbers in parentheses refer to a list of references at the end of this standard.

6.4.1 Always develop incident-specific detection strategies to inform the selection of risk control measures and the overall status of the emergency. Choice of instruments and sampling methodologies should consider the following:

6.4.1.1 Linear range;

6.4.1.2 Limit of detection;

6.4.1.3 Cross-sensitivities;

6.4.1.4 Response times;

6.4.1.5 Interferences;

6.4.1.6 Recommended operating environment;

6.4.1.7 Detector specificity;

6.4.1.8 Quantitative and qualitative capabilities; and

6.4.1.9 Operating requirements.

6.4.2 A list of technologies for which there is data demonstrating their performance for the detection of fentanyl and fentanyl-related compounds is found within the InterAgency Board (IAB) recommendations report (**2**).

6.5 *Sampling and Sample Selection (**2**)*

6.5.1 In responses to incidents potentially involving fentanyl and fentanyl-related compounds, the hazard is assumed to be present, usually because a fentanyl or fentanyl-related compound is visible, or a patient is exhibiting symptoms of opioid exposure. If there is no visible material, a trace technique is required.

6.5.2 Trace techniques can detect amounts which are difficult to see without magnification. For this reason, samples are generally taken by swabbing a surface and desorbing the collected material off the swab into the instrument of interest.

6.5.3 When sufficient sample is available (for example, milligrams or more), various options for detection can be used, each with its own benefits and shortcomings.

6.6 *PPE Recommendations (**1**, **2**, **4**, **5**)*

6.6.1 PPE is the last line of defense in the hierarchy of controls; PPE alone is not sufficient to ensure protection from fentanyl and fentanyl-related compounds. Each agency is responsible for conducting its own risk assessment to determine the appropriate PPE for its individual members. In addition, each agency must develop specific standard operating procedures related to the selection, use (including proper donning and doffing), and care (decontamination, possible reuse, or disposal) of PPE, and periodically train its members in these procedures.

6.6.2 Each agency should also determine the risk level based on an assessment of the specific mission responsibilities and work environment that may include the presence of specific hazards and the likelihood of exposure during operations. The risk assessment should consider the amount and reliability of available information regarding the potential presence of fentanyl or fentanyl-related compounds, and duration and proximity to materials, specifically the first responder's expected proximity to bulk materials, and the type of work that is to be performed.

6.6.3 For emergency response personnel PPE selection, recommendations are based on a risk level determined by two major factors: the PPE wearer's possible exposure to fentanyl or fentanyl-related compounds and the wearer's operational response function. It is important to recognize that the exposure level initially selected can change and PPE should be adjusted accordingly. Additionally, higher levels of PPE may be necessary to protect responders from exposure to other chemicals that may also be present in addition to fentanyl. Personnel, equipment, and tactics can be deployed, evaluated, and downgraded depending on the identification of the substance or level of potential contamination.

6.6.4 As the principal hazard for exposure to fentanyl and fentanyl-related compounds is respiratory, respiratory protection is recommended whenever there is moderate risk or higher. In all cases, first responders should wear gloves (NIOSH only recommends the use of nitrile gloves with a minimum thickness of 5 ± 2 mil (**1**, **6**)) to prevent potential transfer of opioid powders and residues to their bodies, where later re-aerosolization could cause subsequent exposure by inhalation or through mucous membranes. As the risk increases, full skin coverage is recommended for the same reason. PPE recommendations for high-risk situations include full skin coverage provided by an ensemble certified against the appropriate standards, such as NFPA in the United States, that integrates suitable respiratory protection. Production laboratories may include various liquid chemicals, and in such cases the ensemble must provide dermal and respiratory protection from vapors and liquids as well.

6.6.5 The IAB provides a table that describes the physical features and general performance characteristics of recommended PPE items. Several options are described, along with approaches for their integration as an overall ensemble. These should be reviewed before procuring any equipment.

6.6.6 All PPE should be used in accordance with OSHA's HazMat operations (29 CFR 1910.120) and PPE standard (29 CFR 1910.132). When required, respirator use should be in the context of a comprehensive respiratory protection program in accordance with the OSHA respiratory protection standard (29 CFR 1910.134) and other requirements.

6.6.7 Responders who need to wear respirators must be medically cleared, trained, and fit-tested for respirator use. Detailed information on respiratory protection programs, including fit-testing procedures, can be accessed at OSHA's respiratory protection eTool (**5**).

6.6.8 Selected PPE must be donned in the correct order to provide effective protection against contact with fentanyl and fentanyl-related compounds. The specific donning order depends on the PPE items comprising the ensemble, as the donning process is affected by how interfaces are formed. All PPE should be donned in accordance with an established standard operating procedure, under supervision, and with assistance as needed. While taping may be recommended for some interfaces, it is important to use tape that does not degrade protection. For example, when tape is removed during doffing (particularly a tape with strong adhesive, such as duct tape) it can tear the garment. Respirators should never be taped to the hood of a protective coverall or other PPE—this can disrupt the fit of the respirator, which affects its protective performance.

6.6.9 Extreme care must be exercised when doffing PPE following use where contamination has occurred or is suspected. A specific sequence for doffing the PPE must be followed, in an order that prevents any contamination transfer

from the PPE to the wearer or others, and the following considerations should be included in standard operating procedures for doffing ensembles with known or suspected contamination.

6.6.9.1 The wearer must assume that any surface could be contaminated.

6.6.9.2 All doffing must be performed under supervision and with assistance as needed.

6.6.9.3 The last items removed should be the face/eye protection or respirator and inner nitrile gloves.

6.6.9.4 Anytime the wearer or an individual assisting the wearer in the doffing process touches a potentially contaminated surface or PPE item, the wearer or assisting individual must rinse their gloved hands with an appropriate decontamination solution that does not cause the gloves to degrade.

6.6.9.5 For some types of ensembles, it is possible to cut off the garment to permit easier doffing without contacting contaminated surfaces. If cutting of the garment is performed, then the procedures used for the cutting process should be accounted for in the garment's design (for example, the placement of seams and closures).

6.6.10 Each agency should ensure that it develops specific standard operating procedures covering all elements of use including donning, doffing, and disposing of PPE following use. If PPE is contaminated, it must be isolated, contained, and disposed in accordance with federal, state, and local regulations, as applicable to the specific jurisdiction.

6.6.11 All agencies that engage in response operations where responders may need to use PPE against fentanyl or fentanyl-related compound exposure must train their key members at least annually in these procedures. IAB PPE recommendations are based on recognized consensus standards that have been applied to PPE, including protective clothing and respiratory equipment. Referenced standards and attributes should be part of any purchase specifications for selecting PPE.

6.7 *Decontamination Recommendations (1, 2, 7)*

6.7.1 Responders who come into contact with fentanyl on their skin should immediately wash the affected area with cool water and soap, taking care not to break the skin or scrub an open wound.

6.7.2 Most fentanyl and fentanyl-related compounds are water soluble, so expedient decontamination (rinsing) of any contacted areas with water is advisable. Fentanyl in its hydrochloride form (the most common street form) is more soluble than the citrate form (medical grade). Both are more soluble than the free base. Consider adding soap to the wash water to account for the slightly soluble free base. Splashing should be kept to a minimum to avoid aerosolization of the materials. It is not recommended to use bleach, alcohol-based solutions, or high pH soaps, as they all may enhance dermal absorption of fentanyl and fentanyl-related compounds.

6.7.3 It is not recommended to use alcohol-based hand sanitizers to decontaminate as they do not remove fentanyl and fentanyl-related compounds and may enhance absorption of fentanyl through the skin.

6.7.4 All contaminated clothing should be removed and laundered, being careful not to disturb any contaminated areas. Consider dampening the clothing prior to removal with a fine water mist to minimize re-aerosolization of small particles.

6.7.5 All contaminated disposable PPE should be placed in durable polyethylene bags and disposed of properly. Decontamination recommendations found within the IAB report are based upon scientific studies available at the time the document was developed.

6.8 *Medical Countermeasures (2, 8, 9)*

6.8.1 It is important to have an emergency medical technician (EMT) or other medical personnel available if there is a risk of fentanyl exposure.

6.8.2 The IAB recommends that all first responders who may encounter fentanyl, particularly law enforcement, be aware of symptoms related to the effects of fentanyl and accidental fentanyl exposure. These symptoms include pinpoint pupils, excessive sleepiness, not responding to loud voices, inadequate or absent breathing, and cyanosis (patient appears blue).

6.8.3 If a patient possesses paraphernalia consistent with opioid use, has a history consistent with opioid use, or shows symptoms of an opioid toxidrome, an EMT or medically trained responder may deem it necessary to administer naloxone.

6.8.3.1 Naloxone is a liquid, administered intramuscularly by auto-injection, as a nasal spray, or intravenously. It is available over the counter in many jurisdictions. Only medically trained responders with experience treating victims of fentanyl exposure should administer naloxone.

6.8.4 The IAB provides the following recommendations for jurisdictions implementing or considering implementing medically trained responder-administered naloxone for opiate toxidromes:

6.8.4.1 Confirm there are no state or jurisdictional statutes or regulations precluding law enforcement officers from functioning in this capacity;

6.8.4.2 Seek medical advice from a local EMS medical director;

6.8.4.3 Establish an opioid toxidrome treatment protocol within jurisdictional guidance and requirements;

6.8.4.4 Implement training for responders on opioid toxidrome treatment; and

6.8.4.5 Implement response protocols with interdisciplinary representation.

7. Guidance for the Use of Field Detection Technology for Fentanyl and Fentanyl-related Compounds

7.1 Currently, several types of field portable detection technologies are used for field detection of fentanyl and fentanyl-related compounds. This guide only considers instruments and assays specifically designed for use while in the field and does not consider laboratory-based instruments, although field portable instruments could be used in a laboratory setting. These technologies include gas chromatography/mass spectrometry (GC/MS), mass spectrometry (MS) alone (sometimes referred to as high pressure mass spectrometry (HPMS)), ion mobility spectrometry (IMS), Fourier transform infrared spectroscopy (FTIR, specifically instruments that use attenuated total reflection (ATR) as the sampling technique), Raman

spectroscopy, surface-enhanced Raman spectroscopy (SERS), colorimetric assays, and immunoassays. When these analytical techniques are used for field detection applications, they are often not being utilized to their full potential as used in a forensic science service provider's laboratory. Thus, the field practitioner should be familiar with the differences.

7.2 Strengths and weaknesses of various field detection technologies are shown in Table 1. Note that these are only applicable to products that are specifically designed for use while in the field (for example, typically battery operated and portable). In general, products designed for use in the field have limitations that are different than those of products designed to be used in a laboratory environment.

7.3 While bulk detection technologies cannot detect trace quantities (≤1 µg total sample amount), most trace detection technologies can successfully test a bulk sample (>1 µg total sample amount) with appropriate sample preparation/dilution. In general, trace detection technologies that can also test bulk samples with proper sample preparation/dilution include GC/MS, MS, and IMS; sample dilution is highly recommended to avoid overloading the detectors with sample. Bulk detection technologies include Raman spectroscopy, SERS, FTIR spectroscopy, immunoassays, and colorimetric assays. SERS, immunoassays, and colorimetric assays may also be able to detect trace amounts of sample.

7.4 *Best Practices for Field Detection:*

7.4.1 For optimal use of field instruments and assays to screen suspect samples for fentanyl and fentanyl-related samples, it is important to remain disciplined and focused and to follow your agency's established protocols.

7.4.2 Leverage all visual clues such as sample characteristics and situational context of the location when determining the first steps for testing and sample characterization (see Table 1 and Table 2).

7.4.3 Using a combination of technologies offers advantages.

7.4.3.1 Certain technologies and assays are designed for bulk or trace detection. In some cases, a trace detection instrument may become overloaded if used for bulk analysis; in others, an instrument designed for bulk detection may not have the sensitivity required to identify fentanyl at concentrations found in commonly encountered illicit "street" samples.

7.4.3.2 By using multiple detection technologies, for example Raman spectroscopy combined with an immunoassay, it is possible to arrive at an informed opinion regarding the presence or absence of fentanyl. If a Raman spectrometer fails to detect fentanyl but its presence is noted by immunoassay, it may be reasonable to conclude that a responder has encountered relatively dilute drugs, although still hazardous, as opposed to potentially higher purity material that presents higher levels of hazard and exposure danger.

7.4.3.3 When using multiple technologies with limited amounts of sample, a nondestructive method (for example, FTIR, Raman) can be used initially and the same material then analyzed by a destructive method.

7.4.4 Minimize impacts of the environment (for example, sun, wind, and rain) on the measurement process.

TABLE 1 Strengths and Weakness of Field Detection Technologies

Detection Technology	Advantages	Disadvantages
GC/MS	High sensitivity and selectivity Low false-positive and false-negative rates Gas chromatograph (GC) separation step enables detection of multiple target chemicals in complex mixtures Some systems can operate just the MS in a real-time vapor detection mode	Requires multiple manual sample manipulations in full GC/MS mode Longer times from sample introduction to result than many of the other detection technologies Detectors can be overloaded by introducing too much sample Much larger footprint (size and weight) than other portable systems Equipment is more expensive than other available technologies and assays
HPMS	High sensitivity Low false-positive rate Rapid analysis and reporting	Detectors can be overloaded with sample if trace sampling guidance is not followed, requiring bake-out before it can be used again Current HPMS systems often have small libraries focused on high-hazard threats
IMS	High sensitivity Rapid analysis and reporting	Generally, only small libraries are available Can be prone to false positives Can have problems with complex or "dirty" samples; overloading requires long bake-out before instrument can be used again
FTIR	Can measure a wide variety of compounds Large libraries available Nondestructive Rapid analysis and reporting	Target components can be difficult to detect at <10 % levels in a sample Can be difficult to resolve mixtures of compounds
Raman	Can measure through clear containers and packaging; some products can also measure through opaque containers Large libraries available Nondestructive Rapid analysis and reporting Mixture analysis available	Target components can be difficult to detect at <10 % levels in a sample Can be difficult to resolve mixtures of compounds
SERS	Can often achieve low parts-per-million sensitivity	Requires multiple manual manipulations Requires specific libraries matched to the SERS substrate and Raman excitation wavelength
Colorimetric Assays	Low cost Sensitive	Colored samples, some matrices, and cross-reactivity can interfere with interpretation of color changes
Immunoassays	Low cost Sensitive Low false negatives reported for fentanyls Fentanyl analogues can also be detected	Subject to false positives (can have cross-reactivity with some other narcotics)

TABLE 2 Recommendations for Analysis Based on Sample Attributes, Components, and Characteristics

NOTE 1—This table contains recommendations for the analysis of samples that may be encountered. Guidance within the table may not be applicable for all situations; proceed as appropriate for the sample and analysis conditions. Before adopting any recommendations from this table, appropriate safety considerations, PPE, and manufacturer's instructions on the use of an assay or instrument should be reviewed and followed (see Section 6).

Sample Attributes	Descriptions and General Recommendations	Colorimetric	FTIR	GC/MS	HPMS	IMS	Immuno-assay	Raman
Absorbed on a material (paper, dense cellulose fibers, coffee filters, cardboard, paper towels, or other materials)	If these materials are dark-colored, they can trap heat and represent an ignition hazard when scanned with laser-based instruments (for example, Raman).	Use a portion of the material as the sample or extract the chemical out of the material and assay the extract. Do not use acids for extraction—they can turn the absorbent materials dark and the extracts may contain interfering components. Colored absorbent materials may interfere with or mask results.	Treat a small piece as a solid sample (can work when absorbent material does not interfere with characteristic target compound peaks).	Swab sample and extract into solvent. If material interferes with the extraction solvent, consider using evidence tape to capture particulates and then perform solvent extraction.	Use swab. Sample vapor if volatile.	Use swab. Sample vapor if volatile.	Swab across sample or extract sample out of material with water or saline. Perform a serial swab dilution (run most dilute first).	Use scan delay and step away from instrument as scan proceeds. Reduce laser power or integration time of scan. Extract from material and scan in solvent (scan blank solvent to identify background peaks). Also consider using evidence tape to transfer particles to the tape and focus the laser on those particles.
Bulk/high purity samples (if sample is visible to the naked eye, consider it bulk)	High-purity bulk samples may saturate detectors in some instruments, dilutions are recommended. Otherwise, consult manufacturer's instructions.	Use amounts recommended in kit instructions, avoid over saturation. Consider running a diluted sample.	Consult manufacturer's instructions.	Swab the surface or sample to be tested. Perform a serial swab dilution (run most dilute first).	Swab the surface or sample to be tested. Perform a serial swab dilution (run most dilute first).	Swab the surface or sample to be tested. Perform a serial swab dilution (run most dilute first).	Swab across sample or dissolve in water/saline. Consider running a diluted sample.	Consult manufacturer's instructions.
Capsules	If the instrument cannot scan through the capsule, empty content into a plastic bag or vial. Alternately, a capsule can be pierced with a needle to collect powder/residues from the interior. Granular capsule content may need to be ground to powder for some tests – only do this if it is safe.	Granular capsule contents may be slow to dissolve (grind to powder if safe to do so). Alternatively, material can be removed from capsule using a needle to pierce the shell.	Granular capsule contents may need to be ground to powder (if safe to do so).	Dissolve capsule contents in solvent. Alternatively, a needle can be used to pierce the shell and material can be removed from capsule and rinsed with solvent.	Crush capsule content into powder and swab if safe to do so. Perform a serial swab dilution (scan most dilute first). Alternatively, a needle can be used to pierce the shell and material can be removed from capsule and rinsed with solvent.	Crush capsule content into powder and swab if safe to do so. Perform a serial swab dilution (scan most dilute first). Alternatively, a needle can be used to pierce the shell and material can be removed from capsule and rinsed with solvent.	Dissolve capsule contents in water or saline solution. Alternatively, a needle can be used to pierce the shell and material can be removed from capsule and rinsed with water or saline.	Attempt to scan through ends of capsule. Granular capsule content may require multiple scan spots. Alternatively, material can be removed from capsule and treated as an uncontained solid.

TABLE 2 *Continued*

Sample Attributes	Descriptions and General Recommendations	Colorimetric	FTIR	GC/MS	HPMS	IMS	Immuno-assay	Raman
Clear/translucent glass or plastic (for example, smoking pipe)	Residues in interior of pipe can be sampled.	Scrape material out of the pipe and treat as a solid sample.	Scrape material out of the pipe and treat as a solid sample.	Swab the interior surface or sample to be tested. Perform a serial swab dilution (run most dilute first).	Swab the interior surface or sample to be tested. Perform a serial swab dilution (run most dilute first).	Swab the interior surface or sample to be tested. Perform a serial swab dilution (run most dilute first).	Scrape material out of the pipe scraped and dissolve in water or saline.	Scan in "point and shoot mode" and focus laser on residues in the pipe. Scrape material out of the pipe and treat as a solid sample.
Dark background (sample presented against/in contact with dark background)	For laser-based scanning instruments (for example, Raman) heat can be trapped and create an ignition hazard.	If colored material in contact with sample can transfer into the assay, this may interfere with or mask results.	Separate from background and follow any other appropriate sample handling guidance.	Swab the surface or sample to be tested. Perform a serial swab dilution (run most dilute first).	Swab the surface or sample to be tested. Perform a serial swab dilution (run most dilute first).	Swab the surface or sample to be tested. Perform a serial swab dilution (run most dilute first).	Swab across sample or dissolve in water or saline.	Separate from background if possible, otherwise treat as a dark sample (potential ignition hazard).
Dark samples or samples containing dark spots and specks	Sample may be thermally sensitive or an ignition hazard. Use a minimal amount of sample material to increase user safety. Recommended to confirm if the material is explosive (can use an ignition test: use a cotton swab to swab a trace of sample and observe if it sparks in the flame of a propane torch). Do not sample material if there is any concern. Sample different components (dark particles vs. light particles) if heterogeneous.	Colored samples may interfere with or mask results.	Do not use anvil for potentially explosive samples.	Swab the surface or sample to be tested. Perform a serial swab dilution (run most dilute first).	Swab the surface or sample to be tested. Perform a serial swab dilution (run most dilute first).	Swab the surface or sample to be tested. Perform a serial swab dilution (run most dilute first).	Swab across sample or dissolve in water or saline.	Scan in vial with cap removed or loosen or remove seal in other types of containers. Use scan delay and step away from instrument as scan proceeds. Reduce laser power or integration time of scan.
Explosive/ energetic material (known or suspected)	Ignition/explosive hazard. Use a minimal amount of sample material to increase user safety. Do not sample material if there is concern.	Colored samples may interfere with or mask results.	Do not use anvil for potentially explosive samples.	Swab the surface or sample to be tested. Perform a serial swab dilution (run most dilute first).	Swab the surface or sample to be tested. Perform a serial swab dilution (run most dilute first).	Swab the surface or sample to be tested. Perform a serial swab dilution (run most dilute first).	Swab across sample or dissolve in water or saline.	Scan in vial with cap removed or loosen or remove seal in other types of containers. Use scan delay and step away from instrument as scan proceeds. Reduce laser power or integration time of scan.

TABLE 2 *Continued*

Sample Attributes	Descriptions and General Recommendations	Colorimetric	FTIR	GC/MS	HPMS	IMS	Immuno-assay	Raman
Fluorescent or colored glass containers	Amber, brown, green, and blue glass or plastic bottles can generate fluorescence when scanning through the container. Always carefully inspect sealed containers, or packages, before opening. Take appropriate precautions if chemical residues are present on outside surfaces as they may be potentially explosive peroxides. Additionally, opening containers can allow volatile chemicals of interest to escape.	Remove portion of sample from container, consult manufacturer's instructions. Colored materials in contact with the sample may interfere with/mask results.	Remove portion of sample from container, follow instructions appropriate for sample type.	Remove portion of sample from container, follow instructions appropriate for sample type.	Remove portion of sample from container, follow instructions appropriate for sample type.	Remove portion of sample from container, follow instructions appropriate for sample type.	Remove portion of sample from container, follow instructions appropriate for sample type.	If container is fluorescent, remove a portion of sample and scan in a vial or clear plastic bag. Use a laser wavelength that reduces or minimized fluorescence.
Fluorescent samples	Samples that generate high fluorescence interfere with Raman results.	Colored samples may interfere with/mask results.	Review manufacturer's guidance for any issues that might result from fluorescent samples.	Fluorescence should not affect this analysis. Follow any other appropriate sample handling guidance.	Fluorescence should not affect this analysis. Follow any other appropriate sample handling guidance.	Fluorescence should not affect this analysis. Follow any other appropriate sample handling guidance.	Review manufacturer's guidance for any issues that might result from fluorescent samples.	Use laser wavelength that reduces or minimizes fluorescence. Analyze sample using SERS if available.
Frosted or opaque container of sample	Examples: foam cups and soda cans. Always carefully inspect sealed containers, or packages, before opening. Take appropriate precautions if chemical residues are present on outside surfaces as they may be potentially explosive peroxides. Additionally, opening containers can allow volatile chemicals of interest to escape.	Remove portion of sample from container, consult manufacturer's instructions.	Remove portion of sample from container, consult manufacturer's instructions.	Remove portion of sample from container, consult manufacturer's instructions.	Remove portion of sample from container, consult manufacturer's instructions.	Remove portion of sample from container, consult manufacturer's instructions.	Remove portion of sample from container, consult manufacturer's instructions.	Most instruments will not be able to scan through the container. Remove small amount of sample and scan in vial or clear plastic bag.

TABLE 2 *Continued*

Sample Attributes	Descriptions and General Recommendations	Colorimetric	FTIR	GC/MS	HPMS	IMS	Immuno-assay	Raman
Gases/vapors	Includes vapors above liquid/solid samples.	Not compatible.	Not compatible with type of FTIR instruments considered for this standard that are designed for analysis of solid and liquid samples.	Use vapor sampling mode.	Use vapor sampling mode.	Use vapor sampling mode.	Not compatible.	Not compatible with type of Raman instruments considered for this standard that are designed for analysis of solid and liquid samples.
Heterogeneous samples	These include granular samples with a variety of colors or consistencies across the granules, or layered liquids. Different types of layered materials or solid particles may have different chemical compositions. Where possible, physically separate and test components separately.	Granular materials may be slow to dissolve (grind to powder if safe to do so).	Granular materials may need to be ground to powder (if safe to do so).	Swab to collect a representative sample or solubilize 1 to 2 mg in suitable solvent and dilute.	Swab to collect a representative sample. Perform a serial swab dilution (run most dilute first).	Swab to collect a representative sample. Perform a serial swab dilution (run most dilute first).	Swab to collect a representative sample or dissolve in water or saline.	Physically separate and treat each component as its own sample or scan at several spots to capture potentially different chemical components across granules or layers.
Large piece of solid material	Remove a portion of any opaque/non-transparent wrappings to get access to underlying sample.	Scrape off small portion.	Scrape off small portion.	Swab the surface or sample to be tested. Perform a serial swab dilution (run most dilute first).	Swab the surface or sample to be tested. Perform a serial swab dilution (run most dilute first).	Swab the surface or sample to be tested. Perform a serial swab dilution (run most dilute first).	Swab across sample or dissolve in water or saline.	Scrape off small portion and scan in a vial or clear plastic bag. In “point and shoot mode” hold nose of instrument to surface. If available, use scan delay and have operator step away from sample during scan.

TABLE 2 *Continued*

Sample Attributes	Descriptions and General Recommendations	Colorimetric	FTIR	GC/MS	HPMS	IMS	Immuno-assay	Raman
Liquids and gels		Remove portion of sample from container, consult manufacturer's instructions as needed.	For nonvolatile liquids place a drop of liquid on the sampling area. Do not use anvils. For volatile liquids use an appropriate sample accessory (if available) as a protective cap during scanning. Can also saturate a swab with the liquid and apply to the sampling area. Do not press hard on the swab or the swab materials may end up in the scan.	Can directly introduce sample into GC or sample the vapors above the liquid if it has suitable vapor pressure. If injecting sample directly, consider running a split sample to minimize chance of overloading the system. Alternatively, swab with a cotton swab wetted with solvent, extract the sample out of the swab. Samples may need further dilution for analysis. Some systems provide a thermal desorption probe that can be used to sample liquids directly off a swab or from a capillary tube/toothpick (see manufacturer's instructions).	Vapor above liquid can be directly sampled or swab sample and analyze vapor from the swab. Place a drop of liquid onto a swab, allow to dry, perform a serial swab dilution (scan most dilute first). If sample is visible to the naked eye, consider it bulk.	Vapor above liquid can be directly sampled or swab sample and analyze vapor from the swab. Place a drop of liquid onto a swab, allow to dry, perform a serial swab dilution (scan most dilute first).	Swab (dilute with water or saline as needed).	If uncontained, place small amount in a vial for scanning. Collect sample on a cotton swab, hold over nose cone or remove nose cone and scan with bare probe for better focus. Collect in capillary tube or pipette tip, scan through tube or tip. For puddled liquids (6 mm or deeper), in "point and shoot mode" place nose cone close to top of liquid, or scan with bare probe for better focus. Do not touch the underlying surface.

TABLE 2 *Continued*

Sample Attributes	Descriptions and General Recommendations	Colorimetric	FTIR	GC/MS	HPMS	IMS	Immuno-assay	Raman
Plastic bags (translucent) containing powders, pastes, pills, or crystals	Remove portion of sample from bag, follow instructions appropriate for sample type. Residues of powder may be removed from the bag by piercing with a needle (cover puncture with tape after obtaining sample via needle). Residual powders from pills or tablets can be collected by swabbing the inside of the bag. Always carefully inspect sealed bags before opening. Take appropriate precautions if there are chemical residues on outside surfaces.	Remove portion of sample from container, consult manufacturer's instructions.	Remove portion of sample from container, consult manufacturer's instructions.	Remove portion of sample from container, consult manufacturer's instructions. Residual powders from pills or tablets can be collected by swabbing the inside of the bag.	Remove portion of sample from container, consult manufacturer's instructions. Residual powders from pills or tablets can be collected by swabbing the inside of the bag.	Remove portion of sample from container, consult manufacturer's instructions. Residual powders from pills or tablets can be collected by swabbing the inside of the bag.	Remove portion of sample from container, consult manufacturer's instructions. Residual powders from pills or tablets can be collected by swabbing the inside of the bag and dissolved in water or buffer.	Remove material from bag and treat as solid or pill sample. In "point and shoot" mode press laser against bag and hold in place; ensure there is enough material to allow scanning. Avoid scanning air, labels, or ink on bag.
Pill/tablet	If the pill or tablet has a coating, scrape some off to allow the underlying surface to be sampled, or break the pill or tablet in half and scan the interior. Alternately, a needle can be used to pierce the pill and collect small amounts of interior material. Testing both the coating and interior of the pill or tablet is recommended. Alternatively, residual powders in pill containers can be sampled.	Material may need to be ground to powder (if safe to do so). Alternatively, a needle can be used to pierce the pill and collect small amounts of interior material, or residual powders in a container or bag containing pills or tablets can be collected by swabbing the container.	Material may need to be ground to powder (if safe to do so). Alternatively, a needle can be used to pierce the pill and collect small amounts of interior material.	Break, crush, or pierce with a needle to collect small amounts of interior material and swab. Alternatively, residual powders in a container or bag of pills or tablets can be collected by swabbing the container. Perform a serial swab dilution (scan most dilute first).	Break, crush, or pierce with a needle to collect small amounts of interior material and swab. Alternatively, residual powders in a container or bag of pills or tablets can be collected by swabbing the container. Perform a serial swab dilution (scan most dilute first).	Break, crush, or pierce with a needle to collect small amounts of interior material and swab. Alternatively, residual powders in a container or bag of pills or tablets can be collected by swabbing the container. Perform a serial swab dilution (scan most dilute first).	Break or crush into powder, dissolve and dilute in water or saline solution. Alternatively, a needle can be used to pierce the pill and collect small amounts of interior material; or residual powders in a container or bag of pills or tablets can be collected by swabbing the container.	In "point and shoot mode" hold the tablet or the pill against the laser (scan both exterior and break open to scan interior if a coated pill or tablet). Some instruments may have a pill holder adaptor.