technical BRIEF

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Research to Inform Decontamination Strategies, Methods, and Related Technical Challenges for Remediation of a Fentanyl-Contaminated Site

Purpose

This technical brief provides decision makers with a practical summary of recent U.S. EPA scientific information and data related to the technical challenges involved with remediating a fentanyl-contaminated indoor site. The research topics included in this summary are as follows:

- Indoor building decontamination studies evaluating the following aspects:
    - Physical removal of fentanyl;
    - Chemical-based decontamination; and
    - Impact of common diluents, cutting agents, and adulterants on decontamination efficacy.
- Decontamination studies with personal protective equipment (PPE) and/or materials as part of personnel decontamination line procedures (short contact time between PPE material and decontaminant).

Introduction

The U.S. EPA's Homeland Security Research Program (HSRP) helps to develop remediation capabilities to recover from contamination originating from natural disasters, intentional releases, or accidents involving oil or hazardous substances. The hazardous substances can include chemical, radiological, nuclear, and biological materials. The HSRP develops remediation tools with consideration for efficacy, safety, resource demand, logistics, training, and availability.

Figure 1. Lethal doses of heroin (left, 30 mg) and fentanyl (right, 3 mg). Source: New Hampshire State Police Forensic Lab/Public domain

Fentanyl is a highly potent synthetic opioid (approximately 100 times stronger than morphine). "Pharmaceutical fentanyl" was first developed and used for pain management in cancer patients and can be administered for analgesic action of short duration in the immediate postoperative period following surgery. The vast majority of cases of fentanyl-related impairment, overdose and death in the United States are linked to illegally manufactured fentanyl, referred to as "clandestine fentanyl". Clandestine fentanyl is predominantly synthesized in the People's Republic of China and trafficked into the United States via international mail or across the borders. More recently, drug cartels in Mexico have started similar fentanyl synthesis and trafficking efforts. Fentanyl is sold through illegal drug markets for its addictive, opioid intoxication effects. Fentanyl is often added to heroin to increase the potency of the product, and to cocaine to prolong the duration of the effects. Fentanyl can also be found in powders or pressed tablet forms.

Since only a small amount of fentanyl can be deadly, emergency responders and hazmat teams are concerned about their potential exposure while responding to incidents at mixing houses, pill factories, or in makeshift laboratories found in apartments, hotels, houses, garages, and storage facilities. Exposures may also occur when dealing with remnants of laboratories that have been dumped illegally. Other exposure scenarios involve locations of illicit fentanyl smuggling and use, such as correctional facilities.

In 2018, EPA released a fentanyl fact sheet [1] to support EPA On-Scene Coordinators and provide assistance to local, state, tribal, and county hazmat partners in remediation of opioid contamination. The fact sheet provides information regarding the characteristics of fentanyl and fentanyl analogues (such as carfentanil and methylfentanyl) and potential exposure pathways, physical properties, appropriate personal protective equipment (PPE), field detection, sampling, and analysis information. At that time, the information on cleanup of fentanyl contaminated properties was limited to wet chemistry bench-scale fentanyl degradation research [2] and case study accounts that did not represent controlled studies of actual fentanyl remediation efforts, especially from Canada [3].

Figure 2. EPA Fentanyl Fact Sheet (May 2018), available at [https://www.epa.gov/emergency-response/fact-sheet-fentanyl-and-fentanyl-analogs.](https://www.epa.gov/emergency-response/fact-sheet-fentanyl-and-fentanyl-analogs)

This technical document summarizes the results from fentanyl decontamination studies that were conducted under EPA's HSRP. Recognizing the emerging threat of fentanyl and the significant hazards fentanyl poses to the public, EPA also recently updated its Voluntary Guidelines for Methamphetamine Laboratory Cleanup document to include a chapter on fentanyl remediation [4].

Fentanyl as a solid salt (e.g., fentanyl-HCl) has an extremely low vapor pressure. Although not explicitly investigated, any evaporation or natural attenuation is expected to be nonexistent on the time scale of a remediation effort. Fentanyl is also stable in drinking and wastewater based its detection at wastewater treatment facilities.

The decontamination approaches described here are for fentanyl (and more specifically for the hydrochloride salt of fentanyl). No decontamination research has been conducted so far by U.S. EPA related to other fentanyl salts or for fentanyl analogues. While salt form may be expected to have limited impact on chemical-based decontamination, extrapolation of results for chemical-based decontamination to fentanyl analogues should be considered with caution as degradation mechanisms may vary, depending on the specific fentanyl analogue.

Fentanyl Decontamination Research

Fentanyl decontamination studies [5,6] were conducted using small (10 cm^2 surface area) and medium (300 cm^2) size material coupons. The latter, larger size allowed for the inclusion of wipe sampling to determine the amount of fentanyl on the surface. Materials were representative of indoor building materials and were mostly nonporous. Decontaminants were applied using a spray system which applied remediation representative amounts (14 gallon / 1,000 ft^2), equal to 60 $\mu L/cm^2$. Contact time between a decontaminant and building material was one hour except for limited medium size coupon decontamination studies, for which it was up to four hours. Fentanyl mass was quantified as amounts remaining on surfaces after decontamination and in the runoff from each material coupon. Efficacy was determined against recovered fentanyl amounts from controls that were not decontaminated. Fentanyl decontamination studies were conducted to evaluate the oxidative degradation of fentanyl based on percarbonate, hydrogen peroxide, peracetic acid, and hypochlorite (chlorine bleach) chemistries.

Building Decontamination by Physical Removal

Physical removal of fentanyl salts from surfaces can occur either through spraying, wiping or vacuuming of surfaces. A water spray, with or without detergent, physically removed 70–90% of fentanyl from a nonporous surface, but all fentanyl was recovered in the runoff [5]. As fentanyl does not immediately dissolve in water, on several occasions, a clumping of fentanyl salts on the surface was observed. Wiping of fentanyl from surfaces can be effective, but fentanyl would be transferred to the wipe itself [5]. No experimental data has been collected on the efficacy of vacuuming surfaces contaminated with fentanyl. If vacuuming is warranted, a commercial grade vacuum cleaner equipped with a HEPA dust collection system (HEPA-filtered exhaust) is recommended. It should be noted that vacuuming does not remove all particulate surface contamination and can actually cause particles to resuspend into the air. Though HEPA filters are designed to trap particles in the size range of fentanyl powders, it is possible that if the HEPA filter is not sealed/seated properly, particles may go around the filter and become airborne again. As such, caution should be used when HEPA vacuuming and personnel must be adequately protected during these activities.

Building Decontamination using Chemical-Based Decontaminants - I

Decontamination efficacies were obtained for 10 decontamination approaches [5,6] using readily available products that utilize several different chemistries. The range of measured efficacies across various nonporous materials (glass, acrylic, laminate, painted drywall, stainless steel, wood) are tabulated in Table 1 from low to high efficacy. Table 1 also shows the percent of unreacted fentanyl that was detected in the runoff liquid. Product information is summarized in Table 2.

Table 1: Decontamination Efficacies against Fentanyl on Various Nonporous Materials.

Decontaminant. See Table 2 for product information	Range of efficacies across materials (%)	Percent fentanyl in runoff (%)	Reference
Water	62 – 95	33 - 80	5
OxiClean	50 – 78	32 - 66	5
Meth Remover	37 – 73	14 – 32	6
ZEP	57 – 78	11 - 55	6
pH 12 Bleach (undiluted)[a]	69	ND	5
Acidified pH 7 Bleach	59 – 91	1.7 – 25	5
Acidified pH 5 Bleach	94 – 98	1.5 – 4.7	5
Acidified pH 5 bleach with surfactant	94 – 99	0.8 – 2.2	5
EasyDecon DF200	93 – 99.3	0.083 – 9.1	5
Dahlgren Decon	86 – 99.5	0.0022 – 0.024	5
[a] Tested on one material only with no determination of amount in runoff (ND)			

Table 2: Decontamination Product Information.

Decontaminant	Vendor	Active Ingredient and concentration (%)	Preparation Notes
Water	N/A	None	None
OxiClean	Church & Dwight	Percarbonate / HP, 0.4% HP	60 g product in 1 L water
Meth Remover	Apple Environment	HP, ~4% (label information)	Proportional mixing of two parts as per manufacturer directions
ZEP Professional Stain Remover with Peroxide	ZEP	HP, ~4% (label information)	Ready to use
pH 12 Bleach (undiluted)	KoK Bleach	Chlorine, 5.5% FAC	None
Acidified pH 7 Bleach	KoK Bleach	Chlorine, 0.55% FAC	1 part bleach; 0.75 parts vinegar; 8.25 parts distilled water
Acidified pH 5 Bleach	KoK Bleach	Chlorine, 0.51% FAC	1.1 part bleach; 1.4 parts vinegar; 7.5 parts distilled water
Acidified pH 5 Bleach with Surfactant	Clorox ProResults garage and driveway cleaner	Chlorine, 0.51% FAC	1 part bleach; 0.66 parts vinegar; 1.5 parts distilled water
EasyDecon DF200[a]	Intelagard	HP and/or activated peroxygen species, 4% HP	Proportional mixing of three parts as per manufacturer directions
Dahlgren Decon	First Line Technologies	Peracetic acid, 1.7% peracetic acid**	Proportional mixing of three parts as per manufacturer directions
[a] EasyDecon DF200 and Decon7 are identical products as licensed from Sandia National Laboratories ** Reported peracetic acid concentration is biased low due to interference with hydrogen peroxide in titration HP: hydrogen peroxide; FAC: free available chlorine			

Despite the occasional large range in efficacies across tested materials, no statistically significant differences were found in efficacy across the nonporous materials. This is indicative of the loose adherence of fentanyl on nonporous surfaces leading to minimal impact of the material on decontamination efficacy. As with water, an occasional clumping of fentanyl on the surface was observed in the presence of these decontamination solutions. This aggregation leads to a lower decontamination efficacy.

Building Decontamination Using Chemical-Based Decontaminants – II

Additional fentanyl decontamination tests with medium size material coupons [5] indicated that most of the residual fentanyl on surfaces after decontamination (evaluated for chemical decontamination with pH 5 bleach with surfactant and Dahlgren Decon) is found in the liquid residue remaining on the surface. This liquid residue can be removed using dry or wet wipes. The combination of chemical degradation and physical removal of the residue results in less fentanyl remaining on the surface, i.e., higher overall efficacy.

An extension of the decontamination contact time from one to four hours improved efficacy (evaluated for Dahlgren Decon product only). This was attributed to the slow dissolution of unreacted fentanyl that had initially clumped together in the presence of the decontaminant on the surface.

Impact of Additives/Diluents on Decontamination Efficacies

Fentanyl and fentanyl related samples often contain additives such as cutting agents, diluents, or adulterants. The presence of various additives (lactose, mannitol, or ascorbic acid) to fentanyl at a 19:1 mass ratio on laminate resulted in noticeably higher fentanyl recoveries following decontamination with either pH 5 bleach with surfactant or Dahlgren Decon [5]. The impact of mannitol and lactose was relatively small while the presence of ascorbic acid resulted in significantly higher recovery of unreacted fentanyl. This large difference can be attributed to the relative reaction rates of these additives with the active oxidant in the decontaminant.

PPE/Gear Decontamination Efficacy Using Chemical-Based Decontaminants

Fentanyl decontamination studies [6] were also conducted using small (10 cm^2 surface area) size material coupons that were representative of PPE or response gear. Decontaminants were applied as described earlier. However, the contact time between the decontaminant and the PPE or response gear material was only five minutes, similar to contact times in a personnel decontamination line. For PPE or response gear material that was visually contaminated with a fentanyl powder, a diluted (1:4) Dahlgren Decon solution degraded fentanyl on surfaces within five minutes to less than 5% fentanyl mass remaining [6]. pH5 bleach degraded fentanyl as well but the time to reach 5% remaining was significantly longer (>15 min) [6]. As with the building material decontamination, an occasional clumping of fentanyl salts on the surface was observed, leading to poorer decontamination efficacy.

Summary of Fentanyl Decontamination Research

Bench-scale fentanyl decontamination testing demonstrated that (1 hr contact time):

- Full strength (non-buffered pH 12) bleach was not very efficacious (69%);
- Acidified chlorine bleach down to neutral pH (EPA's pH adjusted bleach definition) showed degradation of fentanyl-HCl on nonporous surfaces but significant (40-60%) amounts of fentanyl were still present;
- Chlorine bleach acidified to a pH of ~5 is noticeably more efficacious (95-99%) than neutral pH 7 bleach;
- Dahlgren Decon and EasyDECON DF200 yield high (>99%) efficacy after a one-hour contact time with fentanyl-HCl on nonporous surfaces. Note that the decontamination product Decon7 contains the same formulation as the EasyDecon DF200 product;
- Physical removal of fentanyl via runoff was observed to be significant if chemical degradation did not occur;
- Clumping of fentanyl was observed, and it appeared to decrease chemical degradation;
- The presence of additives such as lactose or mannitol does not significantly reduce the efficacy of the Dahlgren Decon and pH5 bleach products. The presence of ascorbic acid (Vitamin C) as an additive to fentanyl will result in a noticeable lower efficacy of these two decontaminants; and
- For decontamination of PPE / responder gear, a 1:4 diluted Dahlgren Decon solution was found to be highly effective (better than 99.5%) for *in situ* degradation of fentanyl within five minutes. Bleach at pH 5 required longer reactions times and tended to physically transfer more fentanyl into runoff water.

Limitations of Decontamination Studies

The following limitations should be considered:

- Results are based on fentanyl-HCl and outcomes may differ for freebase fentanyl or other salts;
- Fentanyl analogues may not react in a similar manner;
- Decontamination efficacy results are limited to nonporous, hard surfaces; porous materials may be harder to clean using these solution-based approaches;
- There are no data on decontamination of porous materials;
- Results do not address formation of possible toxic byproducts formation, although few byproducts would be expected to be as potent as fentanyl. This may need to be considered in the handling of the waste (see fentanyl fact sheet [1] for waste management related information); and

- Results are based on bench-scale laboratory experiments; scaling up to field use should be done with caution.

Conclusions

A release of fentanyl, either intentional or by accident, may require cleanup procedures to ensure a safe return of a facility or infrastructure to its intended purpose. The bench-scale fentanyl decontamination studies summarized here provide information on the selection of chemical decontamination approaches. In reality, any cleanup approach will likely rely on a combination of physical removal and the *in situ* chemical degradation of fentanyl. For example, the hydrogen peroxide-based product Meth Remover, which was reported to be used in the remediation of a fentanyl contaminated home, may not be as efficacious as the abovementioned products—when considering solely the effects of chemical degradation reported above. However, in combination with the physical removal of fentanyl from surfaces through, for example, the wiping of residual decontamination solution from surfaces—as was performed during field use of Meth Remover—high efficacy was obtained with minimal or no fentanyl remaining on the surface. A practical implication of this combination of physical and chemical removal is that an aqueous and/or solid waste stream containing fentanyl, by-products, and other substances may need to be managed in the field. Management of waste streams may be particularly important because demonstrating successful decontamination may be difficult due to fentanyl sampling limitations for both porous and nonporous materials. Hence, many contaminated materials, especially porous ones with additional sampling challenges, may become part of the waste stream.

There are many factors that affect how efficacious a decontaminant is in degrading fentanyl on a surface. The presence of adulterants and diluents can reduce efficacy due to competing demand between these additives and the applied decontamination product. Caution should be used when decontaminating field sites containing unknown quantities of additives and other impurities. Porous materials are more difficult to clean as fentanyl may migrate into pores and crevices, making it less accessible to a decontamination technology. Fentanyl particulates may move through the air and contaminate previously uncontaminated areas or decontaminated areas; in such cases, spraying surfaces may not be practical and volumetric decontamination ("fumigation") approaches may be necessary. Current and planned fentanyl-related research is intended to address these factors that can confound fentanyl clean-up, as well as being able to apply these results to fentanyl analogues.

Disclaimer

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For more information, visit the EPA website at https://www.epa.gov/emergency-response-research/publications-homeland-security-research-topics.

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