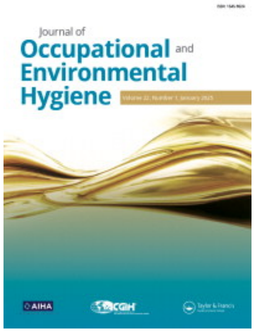

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REPORT

Assessing fentanyl and methamphetamine in air and on surfaces of transit vehicles

Marc Beaudreau*, Pranav Srikanth*, Christopher Zuidema, Martin A. Cohen, Edmund Seto, Christopher D. Simpson, and Marissa G. Baker

Department of Environmental and Occupational Health Sciences, University of Washington School of Public Health, Seattle, Washington

ABSTRACT

Recently, the misuse of fentanyl and methamphetamine has increased in the United States. These drugs can be consumed via smoking a powder, which can subsequently contaminate air and surfaces with drug residue. With limited access to safe consumption sites, this misuse often occurs in public spaces such as public transit, leading to potential secondhand exposures among transit operators and riders. In the Pacific Northwest, transit operators have reported acute health symptoms and safety concerns regarding these drug exposures. Researchers conducted an exposure assessment, sampling air and surfaces for fentanyl and methamphetamine. A total of 78 air samples and 89 surface samples were collected on 11 buses and 19 train cars from four transit agencies in the Pacific Northwest. Fentanyl was detected above the limit of quantification (LOQ) in 25% of air samples (range of concentrations > LOQ: 0.002 to 0.14 µg/m^3) and 38% of surface samples (range of concentrations > LOQ: 0.011 to 0.47 ng/cm^2), while methamphetamine was detected in 100% of air samples (range: 0.003 to 2.32 µg/m^3) and 98% of surface samples (range of concentrations > LOQ: 0.016 to 6.86 ng/cm^2) The highest fentanyl air sample (0.14 µg/m^3) was collected in the passenger area of a train for 4 hr, and would exceed the ACGIH® 8-hr TWA TLV® of 0.1 µg/m^3 if conditions remained the same for the unsampled period. No surface samples exceed the ACGIH fentanyl surface level TLV (10 ng/cm^2). The prevalence of fentanyl and methamphetamine on public transit highlights the need to protect transit operators from secondhand exposure and from the stress of witnessing and responding to smoking events. Future work is needed to evaluate the utility of engineering and administrative controls such as ventilation and cleaning upgrades in reducing exposures on transit, as well as the utility of training and increased workplace support for operators in addressing their health and well-being after observing or responding to drug use events.

KEYWORDS
Exposure assessment; occupational exposures; transit operators

Introduction

Use of fentanyl and methamphetamine outside of a medical context has recently increased in the United States (US), resulting in increased rates of drug-related adverse outcomes such as overdoses (NIH 2021; U.S. Department of Health & Human Services 2021; Spencer et al. 2024; National Institute on Drug Abuse 2024). When used outside of a medical context, both fentanyl and methamphetamine can be consumed by swallowing a pill, nasal insufflation of a crushed pill (i.e., nasal inhalation or "snorting"), injecting a dissolved powder, or smoking powder (commonly off of a heated foil) (National Institute on Drug Abuse 2011). This latter method of consumption has the potential to contaminate air and surfaces with drug residue.

Inadequate access to safe consumption sites and appropriate social services has led to drug use in public spaces such as on public transit, creating potential for secondhand exposure to airborne smoke and surface residue for transit operators and riders (Dovey et al. 2001; Collins et al. 2019; Kerr 2019; Strike and Watson 2019; Horcher 2022). For transit operators, witnessing or responding to drug use events on their vehicle could exacerbate existing job stressors, increase

CONTACT Marissa G. Baker bakermg@uw.edu Department of Environmental and Occupational Health Sciences, University of Washington School of Public Health, Seattle, Washington.
*Co-first authors.

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feelings of burnout, induce unsafe feelings, or cause feelings of panic, distress, or fear (Peters et al. 2021; Kovaleski and Vaccarelli 2023). In the US Pacific Northwest, transit operators have reported acute health effects and concerns about safely operating their vehicles due to secondhand exposure to drugs, and/or witnessing or responding to drug use on their transit vehicles (Horcher 2022; Goodwillie 2023; Harris 2023; Safety & Health Assessment & Research for Prevention 2023).

There has been limited research investigating the acute effects of secondhand occupational exposures to fentanyl and methamphetamine, but case reports among fire-fighter EMS responders (Chiu et al. 2018) and police (Chiu et al. 2019) with presumptive secondhand exposures have detailed acute health outcomes including lightheadedness, palpitations, nausea, and numbness of extremities. It is not clear if these documented health outcomes were the result of secondhand drug exposure, or induced through feelings of distress or panic, due to witnessing a potentially traumatic event. As transit workers spend extended periods on transit vehicles, they may also experience chronic, low-dose exposures, which also have not been investigated in occupational health research or case reports. Consequently, it is a priority for both public and occupational health practitioners and researchers to investigate the potential for secondhand exposure to fentanyl and methamphetamine on transit vehicles.

Among limited prior exposure research, an occupational exposure assessment in a pharmaceutical manufacturing facility found personal airborne fentanyl levels ranging from 0.001 to 13 $\mu g/m^3$ (collected outside respiratory protection), and dermal exposures on the hands of workers ranging from 0.02 to 1,090 ng/cm^2 (geometric mean: 3.5 ng/cm^2) for production workers (workers wore gloves and practiced hand hygiene) (Van Nimmen et al. 2006). In hospital surgical suites where fentanyl is commonly used in intravenous drug delivery, research has found trace levels of fentanyl in air, particularly in exhaled breath near the patient's mouth (Gold et al. 2006; McAuliffe et al. 2006), though other studies were unable to detect fentanyl in a similar setting (Law et al. 2010). Other exposure assessments for fentanyl have relied on worker surveys or interviews to assess exposures and impacts (Chiu et al. 2018, 2019, 2020), but have not directly measured secondhand drug exposures using air or surface sampling techniques.

More studies have investigated occupational and environmental levels of methamphetamine in air and on surfaces. In clandestine methamphetamine manufacturing facilities seized by police, methamphetamine concentrations in indoor air ranged from 0.2 to 7.3 $\mu g/m^3$ (Martyny et al. 2007; Wright et al. 2021). A controlled smoking study found air concentrations of methamphetamine between 300 and 520 $\mu g/m^3$ resulting from a simulated smoke of 100 mg of 91% pure methamphetamine, with higher levels closer to the source (Martyny et al. 2008). This same controlled smoking study measured methamphetamine surface concentrations of 0.17 to 0.31 $\mu g/100\ cm^2$ (mean: 0.23 $\mu g/100\ cm^2$) on horizontal and vertical surfaces after a single simulated smoking event, and 0.22 to 1.50 $\mu g/100\ cm^2$ (mean: 0.68 $\mu g/100\ cm^2$) after a second simulated smoking event, though these air and surface values don't account for loss due to lung absorption (Martyny et al. 2008). This prior work demonstrates the potential for both air exposure and surface concentration after smoking events as exposure pathways for methamphetamine in a variety of occupational and environmental settings.

In the US, enforceable state or federal standards do not exist for fentanyl or methamphetamine exposures originating in the workplace. Table 1 summarizes the regulatory standards and recommended health-based guidelines for fentanyl and methamphetamine in the air and on surfaces. In November 2023, the American Conference of Governmental Industrial Hygienists (ACGIH) adopted an 8-hr time-weighted average (8-hr TWA) Threshold Limit Value (TLV®), and 15-min short-term exposure limit (STEL) for fentanyl, as well as a fentanyl surface contamination TLV (ACGIH 2023). No additional state or federal guidelines exist for fentanyl exposure in workplaces. While individual states have established methamphetamine surface decontamination standards, in general, these are targets for cleaning property previously used for clandestine methamphetamine production and have unknown applicability to secondhand exposures in occupational settings (US EPA 2021). No state or federal guidelines or recommendations could be found for methamphetamine in air.

Here, the potential for transit workers' secondhand exposure to fentanyl and methamphetamine by collecting air and surface samples from transit vehicles in Washington state (WA) and Oregon (OR) is characterized. Currently, there is no widespread agreement on sampling or analysis methods for secondhand drug smoke in a workplace setting, though several laboratories and investigators have validated analytical methods (Van Nimmen and Veulemans 2004; Bureau Veritas 2018; Jeronimo et al. 2024). Federal agencies such as the Occupational Safety and Health Administration (OSHA) or the National Institute for

Table 1. Regulatory and recommended standards for fentanyl and methamphetamine, USA.

	Surface		Air	
	Value	Type	Value	Type
Fentanyl				
American Conference of Governmental Industrial Hygienists (ACGIH)[a]	10 ng/cm^2	Health-based	8-hr TWA: 0.1 μg/m^3 15-min STEL: 0.2 μg/m^3	Health-based
Methamphetamine				
Washington State (Department of Health)[b]	15 ng/cm^2	Health-based	No air standard or guideline in WA	
Oregon State (Oregon Health Authority)[c]	0.5 μg/ft^2 (0.54 ng/cm^2)	Not health-based	No air standard or guideline in OR	
Other US States	No federal surface standard. As of August 2021, at least 21 states have established quantitative decontamination standards for methamphetamine on surfaces, ranging from 0.5 ng/cm^2 to 15 ng/cm^2. No recommended guidelines found.		No US state or federal agency has established a regulatory air value for workplaces or decontamination. No recommended guidelines found.	

[a]Recommended standards, not legally enforceable; no US state or federal agency has regulatorily established a value (ACGIH 2023).
[b]Regulatory standard, unknown applicability to transit (Washington Administrative Code 246-205 2023).
[c]Regulatory standard, applies to properties previously used in the manufacture of methamphetamine (Oregon Administrative Rules 333-040 2000).

Occupational Safety and Health (NIOSH) have not proposed a sampling or analytical method for fentanyl in air or on surfaces, or methamphetamine in the air, though NIOSH methods 9106 and 9109 provide methods for methamphetamine collected on surfaces via wipe samples (NIOSH 2011a, 2011b) With limited research directly measuring secondhand exposure to fentanyl and methamphetamine in occupational settings, the work presented here is a novel exploration of how to appropriately characterize worker exposures even with a lack of guiding methods. This study addresses a major, emerging public and occupational health concern and highlights the need to protect transit workers and prioritize future research.

Methods

In collaboration with five transit agencies in the Pacific Northwest (WA, OR), researchers developed sampling strategies to collect air and surface samples on vehicles from four agencies. Details of the sampling strategies are summarized in Table 2. Routes, runs, and time of day for sampling was informed by data collected from operator and rider reports of drug use and conversations with transit agencies to maximize the potential for drug use to occur during sampling. Researchers were generally not present on transit during sampling to avoid biasing passenger behaviors and to align with transit agencies' safety protocols, but were present during sampling periods for one agency, as required by the transit agency to ensure the safety of equipment and the ability to respond to operator questions or concerns during sampling. This transit agency also requested researchers remove the pumps when trains reversed direction at the end of the line, resulting in some shorter sampling times compared to other agencies.

Researchers also collected repeat environmental air and surface samples from three locations in Seattle, WA (urban core, urban residential, low-density residential), and two locations in or near Portland, OR (urban core, suburban). These samples were collected outdoors in public spaces away from transit spaces (e.g., train tracks, bus stops, transit centers) using the same methods as those collected on buses or trains (detailed subsequently). These samples were used to assess environmental background levels of fentanyl and methamphetamine for comparison to levels measured on transit vehicles and to rule out the possibility that exposures measured in transit were a result of general background environmental contamination.

Air sampling

Area particulate air samples were collected between 6 pm and 12 am using AirChek 5000 pumps (SKC Inc., Eighty Four, PA) calibrated to a flow rate of 2 liters per minute (LPM), connected to a 25 mm 5-micron (μm) nylon filter in a 3-stage black polypropylene total dust cassette. Pumps were calibrated before and after each sampling period to determine an average volumetric flow rate. Samples were collected for varying amounts of time depending on agency-specific protocols and transit route lengths. All samples were analyzed by a commercial laboratory using LC/MS/MS, which informed us via personal communication that recovery decreases below 70% for fentanyl and 85% for methamphetamine when sample time exceeds 4 hr; as such researchers aimed to sample for no more than 4 hr (240 min) when possible (Jason

Table 2. Sampling strategies utilized across four transit agencies.

Agency ID	*n* Shifts sampled	Total *n* (type) vehicles sampled	Air sample locations (*n* samples)	Surface sample locations (*n* samples)	Air sample times (min)	Notes
Trains						
1-Train	9	11 (Siemens 500 series)	• In operator cab (9) • In passenger area near operator cab (8)	• Seatbacks nearest operator cab (8)	59–287	Researchers present on trains during sampling
2-Train	2	8 (Siemens 400/500 series)	• In operator cab (8) • In passenger area near operator cab (8)	• Outside of operator cab door (6) • Seatbacks in middle of train (6) • Behind bench seating in train rear (6)	240–284	Researchers not present on trains during sampling
Buses						
3-Bus	15	1 (New Flyer Xcelsior 60′ articulated)	• On operator's seat (9) • Rear bus: curbside (9) • Rear bus: streetside (9) • Mid-bus: behind electronic reader board (9)	• Shelf near operator (11) • In front of rear ceiling vent (9) • Rear seatbacks: streetside and curbside (28)	240	Researchers not present on bus during sampling
4-Bus	2	10 (New Flyer Xcelsior 60′ articulated)	• On operator's seat (5) • Rear bus in ceiling vent (4)	• Shelf near operator (4) • In front of rear ceiling vent (3) • Rear seatbacks: streetside and curbside (8)	121–267	Researchers not present on bus during sampling; were able to check in with operators throughout sampling

Forbes, Bureau Veritas Industrial Hygiene Lab Director, June 6, 2022).

To sample air on trains (Agency IDs 1 and 2), a cut Kydex thermoplastic panel was fitted into the window of the operator cab door. This panel had a hole into which researchers inserted a sampling cassette and filter facing into the passenger area while concealing the sampling pump inside the operator cab. An additional sampling assembly was placed in the operator's cab.

Researchers collected air samples from the operator on buses (Agency IDs 3 and 4) by placing a pump behind the operator's seat and securing the filter cassette to the seat's headrest. Sampling strategies for the rear of the bus differed between agencies due to agency constraints and preferences on where air sampling apparatuses could be placed. For Agency 3, samples were taken at the far rear of the bus both streetside and curbside by modifying the rear panel that separates the passenger cab from the fire suppression system. Custom fabricated 3D printed cassette holders were mounted into the panel, allowing the sampling cassette to be secured in a discreet and tamper-proof position facing the bus interior. An additional sampling assembly was magnetically affixed behind the reader board at the midpoint of the bus on Agency 3. Researchers collected one sample in the rear of the bus for Agency 4. A sampling pump was secured inside of the rear-most HVAC mixing plenum to prevent tampering, with the filter cassette mounted cabin side and away from the HVAC filter to reduce the impact of the exhaust turbulence.

Surface sampling

Surface samples were collected following laboratory-provided protocol (Bureau Veritas North America n.d.). A single-use 100 cm^2 template was positioned on the surface to be sampled. For each sample, a new two-sided swab head was submerged in methanol, then passed 10 times horizontally (left to right) over the entire surface inside the template and turned over and passed 10 times vertically (bottom to top) over the entire surface inside the template. The swab head was then snapped off into a Teflon-capped glass container for analysis. During the sampling setup, pre-identified areas were cleaned using isopropyl alcohol (IPA) and Luminox; a swab sample was collected from these locations after air sampling was concluded. On buses, surface samples were collected on a shelf near the operator, on the back of seats in the middle and rear of the bus, and the far rear windows (both curbside and streetside). On trains, surface samples were collected outside of the operator door (above the door handle) and on seat backs in the passenger area of the train. Surface samples sought to quantify the fentanyl and methamphetamine deposited on the sampled surfaces during the work shift.

Laboratory and data analysis

After collection, all samples were transported on ice and stored at 0 °C at the University of Washington before shipment on dry ice to the analytical laboratory. Samples were submitted in a total of five batches, with air and surface blank samples submitted with each batch. Samples were submitted to a commercial laboratory accredited by the American Industrial Hygiene Association Laboratory Accreditation Program (AIHA®-LAP) to be analyzed for the mass of fentanyl and methamphetamine using LC/MS/MS in accordance with their OpiAlert method (Bureau Veritas 2018). This method has a laboratory limit of quantification (LOQ) of 1 ng for both fentanyl and methamphetamine. Results were not corrected for recovery as batch-specific recovery results were not provided by the laboratory, though average recoveries for the method were reported via emailed personal communication (Jason Forbes, Bureau Veritas Industrial Hygiene Lab Director, June 6, 2022). For air samples, air concentrations (in μg/m^3) were calculated by dividing the laboratory-reported mass by the sample volume. Time-weighted averages (TWA) were calculated for each sample based on the total sample time. Comparisons made to regulatory or guideline 8-hr TWA values assumed that measured concentrations were representative of 8-hr TWA exposures, given the frequency of reported events on transit vehicles (Pae 2022; Harris 2023).

For surface samples, surface concentrations (in ng/cm^2) were calculated by dividing the laboratory-reported mass by the sampled surface area (100 cm^2). Samples were adjusted for batch-specific blanks; no air or surface blanks had fentanyl above the LOQ; no air blanks had methamphetamine above the LOQ. One of the two surface blanks submitted with sample batch 4 had methamphetamine above the LOQ (blank mass = 1.35 ng), so surface samples in this batch were blank-adjusted.

Air and surface sampling data were summarized descriptively by transit vehicle type (bus/train) and location on the transit vehicle. In addition to the mean, standard deviation (SD), and range of time-weighted average exposures, researchers calculated the number and proportion of samples in which fentanyl or methamphetamine was detected above the LOQ. Measured values were compared to available standards and guidelines as detailed in Table 1, acknowledging that air samples were not collected for a full 8-hr shift. Data analysis was completed in R version 4.2.2. This study was exempt from Human Subjects Division review because no samples or data were collected directly from individuals.

Results

Air and surface concentrations

Researchers submitted 78 air samples and 89 surface samples to the laboratory for analysis. Results from air sampling are presented in Table 3, stratified by type of vehicle (bus or train) and location in the vehicle (operator or passenger area), separately for fentanyl and methamphetamine. Of 45 air samples collected on buses, fentanyl was detected above the LOQ in nine (20%), with concentrations up to 0.04 μg/m^3. Of 23 air samples collected on trains, fentanyl was detected above the LOQ in 11 (48%) with concentrations up to 0.14 μg/m^3. Methamphetamine was detected above the LOQ in all air samples collected on buses and trains, ranging from 0.003 to 2.32 μg/m^3. Fentanyl and methamphetamine in air tended to be higher in passenger areas of vehicles. One train air sample in the passenger area had a fentanyl concentration of 0.14 μg/m^3, exceeding the ACGIH 8-hr TWA TLV of 0.1 μg/m^3; the operator sample taken concurrently was about 80% of this exposure limit (0.078 μg/m^3).

Surface sampling results are summarized in Table 4, stratified by collection location on the transit vehicle. For both buses and trains, measured surface concentrations tended to be higher in the passenger areas though there was evidence of surface contamination throughout the vehicle. The majority of surface samples were 10–100× lower than applicable guidelines and standards. No samples exceeded the WA health-based methamphetamine decontamination standard of 15 ng/cm^2 and no samples exceeded the ACGIH fentanyl surface level TLV of 10 ng/cm^2. The highest methamphetamine surface concentration detected in this study (6.86 ng/cm^2, collected in the rear of a bus) is at about half of the WA state decontamination standard. The highest fentanyl surface concentration detected in this study was 0.47 ng/cm^2, also collected in the rear of a bus.

Environmental concentrations

Researchers collected a total of 15 environmental (background) air samples and 14 environmental (background) surface samples. None of the samples had fentanyl above the LOQ. Four (27%) of the air

Table 3. Air sampling results for fentanyl and methamphetamine, by vehicle type and location.

	Fentanyl (ACGIH TLV: 0.1 μg/m^3)[a]			Methamphetamine		
Vehicle location	*n* samples (n, % >LOQ[b]	Mean (SD) [μg/m^3] for samples > LOQ	Range [μg/m^3] for samples > LOQ	*n* samples (n, % > LOQ[b]	Mean (SD) [μg/m^3] for samples > LOQ	Range [μg/m^3] for samples > LOQ
Bus						
Operator	14 (1, 7%)	NA	0.005	14 (14, 100%)	0.078 (0.22)	0.003–0.86
Passenger[c]	31 (8, 26%)	0.015 (0.014)	0.002 – 0.04	31 (31, 100%)	0.243 (0.609)	0.01–2.32
Train						
Operator	17 (6, 35%)	0.026 (0.027)	0.005–0.078	17 (17, 100%)	0.027 (0.016)	0.01–0.07
Passenger[c]	16 (5, 31%)	0.033 (0.052)	0.005–0.14	16 (16, 100%)	0.037 (0.021)	0.01–0.09

n = number; NA = Not applicable as there was only one sample detected (single value listed in range column); SD = standard deviation.
[a]ACGIH TLV is for inhalable dust, we collected total dust in this study.
[b]A mass detected above the laboratory limit of quantification (LOQ) of 1 ng (for both fentanyl and methamphetamine). For a four-hour air sample at 2 L/min, this would equate to a concentration of 0.002 μg/m^3.
[c]Bus passenger samples were all from behind the bus articulation, in the rear third of the bus; train passenger samples were collected adjacent to the operator cab.

Table 4. Surface sampling results for fentanyl and methamphetamine, by vehicle type and location.

	Fentanyl			Methamphetamine		
Vehicle location[a]	*n* samples (n, % > LOQ[b])	Mean (SD) [ng/cm^2] for samples > LOQ	Range [ng/cm^2] for samples > LOQ	*n* submitted samples (n, % > LOQ[b])	Mean (SD) [ng/cm^2] for samples > LOQ	Range [ng/cm^2] for samples > LOQ
Bus						
Operator	15 (3, 40%)	0.047 (0.056)	0.01–0.16	15 (15, 100%)	0.25 (0.14)	0.063–0.57
Mid Passenger	12 (2, 17%)	0.020 (0.003)	0.018, 0.022	12 (12, 100%)	1.30 (1.74)	0.141–4.58
Rear Passenger	36 (22, 61%)	0.085 (0.13)	0.011–0.47	36 (36, 100%)	0.97 (1.22)	0.063–6.86
Train						
Outside of Operator Door	9 (2, 22%)	0.145 (0.08)	0.015, 0.13	9 (7, 78%)	0.20 (0.32)	0.035–0.93
Passenger	17 (5, 29%)	0.077 (0.075)	0.014–0.17	17 (17, 100%)	0.32 (0.44)	0.013–1.32

n = number; SD = standard deviation.
[a]For bus, mid passenger refers to wipe samples taken between the front and rear door of the bus, rear passenger samples were taken behind the rear door. For train, passenger samples were taken throughout the passenger area (details in Table 2).
[b]A mass detected above the laboratory limit of quantification (LOQ) of 1 ng (for both fentanyl and methamphetamine). For a 100 cm^2 surface sample, this would equate to a surface loading of 0.01 ng/cm^2.

samples had methamphetamine above the LOQ and four (29%) of the surface samples had methamphetamine above the LOQ (detailed in Supplementary Table 1). A typical air sample collected on a bus or train had three times more methamphetamine than the environmental air samples; a typical surface sample collected on a bus or train had about 20 times more methamphetamine than the environmental surface samples (detailed in Supplementary Table 2).

Discussion

To the authors' knowledge, this is the first exposure assessment of secondhand drug smoke and residues on transit vehicles. Fentanyl was present in 25% of air samples and 46% of surface samples, while methamphetamine was found in all air samples and 98% of surface samples. Results presented here confirm the presence of fentanyl and methamphetamine both in the air and on the surfaces of transit vehicles included in this study, and the potential for secondhand exposure through both inhalation and dermal routes. In general, air and surface levels tended to be higher in passenger areas of the transit vehicle, consistent with where these drugs are being smoked. While this exposure assessment did not employ methods specifically to assess riders' exposures, who would be on the transit vehicles for shorter periods than the operators, findings do show the potential of exposure for the riding public. In addition, the surface exposures present throughout the bus indicate that maintenance workers and other transit personnel could also be at risk of exposure due to their work tasks.

There is no broad scientific consensus about what levels of these drugs in air or on surfaces would pose an acute or chronic health risk of concern to transit operators, who often work 8–10 hr shifts (U.S. Department of Transportation 2022). In November 2023 the ACGIH produced health-based guidelines for fentanyl exposure in workplaces, for both chronic exposures (8-hr TWA TLV, 0.1 μg/m^3) and acute exposures (15-min TWA STEL, 0.2 μg/m^3), though these are not regulatorily enforceable (ACGIH 2023). Similarly, using a safety factors approach, research in the pharmaceutical production industry identified a recommended occupational exposure level of 0.1 μg/m^3 for fentanyl in air (Naumann et al. 1996; Binks 2003). In this study, only one measured air concentration exceeded 0.1 μg/m^3, which was found in the passenger area of a train. The air sample collected in the operator cab concurrently was at about 80% of the ACGIH 8-hr TWA TLV (no short-term exposure samples were collected). However, these samples were collected for less than a full 8-hr shift (run time = 240 min) and were total dust samples as opposed to inhalable, so direct comparison to the ACGIH TLV should be done with caution. However, researchers assumed that conditions for the unsampled period are the same as the sampled period, given the frequency of reported events, making exposures exceeding the ACGIH 8-hr TWA TLV likely (Pae 2022; Harris 2023).

While the American College of Medical Toxicology (ACMT) and American Academy of Clinical Toxicology (AACT) stress in their position statement that absorption of fentanyl through the skin is negligible, and touching fentanyl or fentanyl-contaminated surfaces is not believed to pose a clinically meaningful health risk (Moss et al. 2017), Van Nimmen et al. found a correlation between fentanyl hand exposure and urinary excretion, suggesting that the dermal pathway may be the primary route of fentanyl exposure for many workers (Van Nimmen et al. 2006). Similarly, the ACGIH wrote a surface-level guideline for fentanyl (10 ng/cm^2) with a skin notation, indicating toxicity is possible through dermal routes of exposure. No samples exceeded this guideline.

As detailed in Table 1, there are no enforceable state or federal standards for methamphetamine or fentanyl in workplace air. While no samples exceeded the WA health-based remediation surface standard for methamphetamine of 15 ng/cm^2 (Washington Administrative Code 246-205 2023), one sample was at about half of the standard (6.89 ng/cm^2) and 29 (32.6%) exceeded the OR decontamination standard of 0.5 μg/ft^2 (0.54 ng/cm^2) (Oregon Administrative Rules 333-040 2000). However, the OR decontamination standard is not health-based and only has regulatory applicability in facilities where methamphetamine is being manufactured, not where it is being used.

This study did not assess mental or physical health impacts related to secondhand fentanyl or methamphetamine exposure but provides evidence that operators could be exposed at work, creating the potential for health impacts. Compared to research on physical health effects associated with fentanyl and methamphetamine misuse, research is limited to the mental health effects individuals may experience when they observe drug misuse or interact with individuals using drugs in their work environment. Case reports have shown firefighters and law enforcement experience mental health impacts related to opioid overdose responses, and law enforcement professionals have exhibited acute anxiety responses related to unintentional occupational exposure to opioids (Chiu et al. 2019; Persaud and Jennings 2020; Del Pozo et al. 2021); transit operators may experience similar impacts.

Given the presence of both fentanyl and methamphetamine found on public transit in this study, occupational health interventions and evaluations of these interventions, are prudent to reduce exposures and potential health impacts to operators.

Public Health has long supported smoke-free workplaces, and 27 states (plus Washington, DC) have adopted workplace smoking legislation of some type, primarily focused on tobacco smoke (CDC 2024). Enacting or continuing to enforce measures to discourage or ban smoking, including methamphetamine and fentanyl, on public transit is consistent with the public health goal of smoke-free workplaces. Researchers acknowledge that this should be done without further harming individuals who use fentanyl or methamphetamine. Some transit agencies have found success employing unarmed community outreach or safety ambassadors who both discourage inappropriate and illegal behavior while also providing references and referrals for social services to those using drugs openly (TriMet n.d.). Access to safe consumption sites for drug use and other harm-reduction approaches could also be explored, though require policy actions outside of the workplace to be effective.

While elimination is the most effective control for secondhand drug exposures, engineering, and administrative controls can also help to protect operators (NIOSH 2020). Upgrading air filters on transit vehicles to a minimum efficiency reporting value (MERV) of 13 (or to as high of a MERV filter rating as feasible) will improve particulate filtration, potentially resulting in fewer particles reaching the operator or depositing on surfaces. Other methods to increase airflow, such as opening windows or bringing in more outside air through the heating/cooling system will also increase air changes per hour (ACH) though these actions are dependent on passenger and operator preferences and actions. Enhanced cleaning protocols, increased cleaning frequency, and use of solvents that are appropriate for both water-soluble (e.g., fentanyl) and water-insoluble (e.g., methamphetamine) contaminants could be effective for reducing drug residue on surfaces. Contaminated surfaces that may not be touched by operators or the riding public should also be cleaned, as these are accessed by and may expose transit maintenance workers. However, the real-world best practices and effectiveness of these controls still need to be studied.

Workers should be educated by their employer and/or union on the hazards of secondhand exposure to fentanyl, methamphetamine, and other hazardous substances. This can include updated or more frequent training on topics such as agency protocols that operators should follow when they observe a smoking event or are threatened by a passenger, real and perceived risks related to secondhand drug exposure, and how and when to deploy naloxone if comfortable doing so. Research with police officers and first responders has shown that medically accurate training about fentanyl can increase knowledge in these occupational groups, and correct misconceptions about exposure and risk of overdose (Persaud and Jennings 2020; Winograd et al. 2020; Del Pozo et al. 2021). Employers should also ensure operators have access to mental health support, as observing or responding to emergencies involving drug use could be distressing. Including transit operators and their unions in conversations about how to best support and protect workers exposed to secondhand drugs in the workplace may increase the likelihood of acceptance and adoption of interventions.

In its guidance for emergency responders, NIOSH recommends the use of personal protective equipment (PPE), including nitrile gloves, eye protection, and respiratory protection (P100, N100, or R100) when handling paraphernalia or touching surfaces that may have drug residue or when drugs are visible (NIOSH 2022). This PPE is appropriate for trained personnel who are tasked with the removal of drug paraphernalia and clean-up of visible drug residue but is unlikely to be necessary for transit operators during the normal course of their work. Given PPE relies on individual worker compliance and knowledge of its use, the authors recommend transit agencies prioritize eliminating the hazard or using engineering and administrative controls, though transit operators should be allowed to wear PPE should they choose. Any adopted control should be evaluated for effectiveness.

To the authors' knowledge, this is the first exposure assessment to characterize air and surface concentrations of fentanyl and methamphetamine on transit vehicles and motivates future studies on this and related topics. Expanding the body of research exploring the relationship between workplace exposures and acute and chronic physical and mental health outcomes (assessed either clinically or via a survey) will allow for more actionable results and evidence-based regulatory guidelines to protect workers. Collecting biomarkers of exposure from transit operators and other transit workers who may be exposed, such as maintenance workers, could help inform the relationship between exposure, dose, and health outcomes. As smoking events tend to occur over short periods, characterizing short-term exposures would be more representative of riders and allow for exploration of potential acute impacts.

In this study, researchers only investigated methamphetamine and fentanyl, though there was evidence that other drugs were also present. Characterizing the suite of drug exposures, and how they might interact when smoked together, would allow for a greater understanding of potential health risks and how to deploy controls (such as cleaning) to best protect workers. Expanding this work to other occupations that may face secondhand exposure to drugs at work would also be beneficial for characterizing the workplace burden of these exposures. While the assessment didn't characterize exposures to the riding public, expanding this work to characterize exposures the public may experience would also be of scientific interest.

Limitations

There were several limitations of this work which must be acknowledged. Due to the sampling strategy, researchers were generally not present with equipment, and while this likely reduced observer bias, researchers were unable to comprehensively or consistently document exposure determinants, such as whether or not smoking events occurred during sampling, where smoking events took place, event durations, the substance smoked, etc. To comply with agency requirements and ensure researchers did not disrupt operators or the riding public, sampling protocols differed for each of the agencies worked with, including sampling location, and researcher presence on the vehicles. Lastly, this was a limited-scope assessment, with data collected over a total of 28 nights from 11 buses, 19 trains, and 4 transit agencies. Because the vehicles and times that were chosen for sampling were those identified as having a high probability for smoking events, these data, while representing true conditions in transit vehicles in the Pacific Northwest, should not be taken to be broadly representative or generalizable.

Conclusions

Fentanyl and methamphetamine were frequently found both in the air and on surfaces of the trains and buses in this study, at levels exceeding those observed in environmental (background) samples collected in urban settings. While enforceable regulatory guidelines do not exist for fentanyl and methamphetamine in workplaces, protecting transit operators from secondhand exposures represents appropriate occupational health action. Following the hierarchy of controls by eliminating the hazard on transit is preferred, coupled with engineering and administrative controls such as ventilation and cleaning upgrades, training, and increased operator support. Further research on this topic could investigate the quantitative relationship between exposure, dose, and outcome; evaluate controls for effectiveness and adoption; explore health outcomes related to acute and chronic exposures; and research short-term exposure levels and impacts on the riding public.

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Author contributions

MB, CZ, MAC, ES, CDS, and MGB conceived and designed the work as presented here. MB, PS, CZ, and MGB acquired the data and all authors contributed to analyzing and interpreting the data. MB, PS, CZ, and MGB drafted the manuscript and tables and all authors revised the work critically for important intellectual content. All authors provided final approval of the version to be published and agree to be held accountable for all aspects of the work and ensure that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Disclaimer

The findings reported here are those of the authors alone and do not necessarily reflect the official views or positions of NIOSH, NIEHS, or the agencies who contributed funding to this assessment.

Disclosure statement

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ORCID

Pranav Srikanth http://orcid.org/0000-0003-3815-3697
Christopher Zuidema http://orcid.org/0000-0002-2233-2706
Martin A. Cohen http://orcid.org/0000-0001-9311-3001
Edmund Seto http://orcid.org/0000-0003-4058-0313
Christopher D. Simpson http://orcid.org/0000-0001-7122-371X
Marissa G. Baker http://orcid.org/0000-0003-3136-0490

Data availability statement

The data that support the findings of this study are available from the corresponding author, MGB, upon reasonable request.

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