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An easy to implement approach for laboratories to visualize particle spread during the handling and analysis of drug evidence

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HIGHLIGHTS

- Fluorescent simulate drug brick used to visualize particle spread.
- Multiple processes in analysis lead to particle spread.
- Transfer of particles to surfaces such as heat sealers and wash bottles occurred.
- Repackaging evidence is a potential source of particle transfer to outside the lab.

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Visualization
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ABSTRACT

Recent work has shown that detectable levels of drugs exists on nearly all surfaces within a forensic laboratory – especially within the drug chemistry unit. This is an expected occurrence due to the handling and opening of drug evidence that contains powder material. The process of opening evidence, which produces aerosolized particulate that can settle on surfaces throughout the lab, has never been visualized. This work presents the first attempt to visualize the spread of particulate throughout the laboratory during the analysis of drug evidence and introduces an easy to implement approach laboratories can use to evaluate their specific protocols. By creating two simulated bricks of drugs that contained fluorescent particles, the spread of particulate was able to be monitored throughout the evidence handling process up to and including cleaning of surfaces after analysis. The protocols in this work showed the spread of particulate, prior to cleaning, to be quite extensive, with transfer onto surfaces and items that were handled. In this study, cleaning with methanol after processing the evidence was shown to be effective at removing nearly all particulate that was released in the process. The use of visualization techniques such as this demonstrate promise for helping laboratories identify processes in their own protocols that may contribute to drug background levels and educate forensic chemists how trace residues spread.

1. Introduction

Over the last several years there has been an increasing body of work measuring background levels of drugs in operational environments such as police stations [1,2] and forensic laboratories [3–5]. Most surfaces sampled in these locations have shown detectable levels of one or more drugs, with increased frequency and abundance in the drug chemistry units of forensic laboratories. In one study, an average of over 50 ng cm^{-2} of heroin was found on surfaces [3]. Increased interest in this research area is being driven to address three main points. First, the escalating presence of potent drugs, such as fentanyl [6,7], continues to draw concern over accidental exposure for law enforcement and laboratory personnel. This has led to a renewed interest and focus in developing health and safety protocols for the handling of suspected opioid drug evidence [8–12]. Second is the desire to understand what, if any, implications background levels have on current data quality. Finally, there is a need to grasp the importance of existing drug background levels as instrumentation continues to become more sensitive [13] – nearing the point where detection of background is attainable. While drug background can easily be measured through sampling and analysis, doing so does not provide a complete picture as to the processes that are contributing to the background.

One way to understand the processes that contribute to the drug background is by visualization tools that allow for qualitative or quantitative images or videos to be obtained. Visualization tools have been utilized in several other fields to better understand processes that

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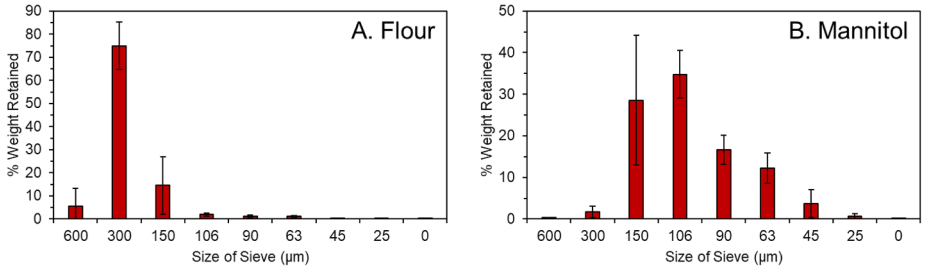


Fig. 1. Particle size distributions for the flour (A.) and mannitol (B.) used in these experiments. Error bars represent the standard deviation of three replicate measurements.

lead to background or contamination. Techniques such as schlieren imaging, which visualizes changes in the refractive index of gases, have been used to model cleanroom air flows to minimize contamination [14]. Another commonly employed process involves the use of fluorescent particles incorporated into simulant samples followed by visualization under ultraviolet (UV)-light. This approach has been used to understand the spread of biohazardous materials in cell sorting processes [15,16], understand the mechanisms of Ebola transmission [17–19], as well as visualize contamination in food handling environments [20] or with medical procedures [21–23].

In this work, fluorescent powder and UV-light visualization were employed to better understand particulate spread during the analysis of a simulated drug brick. By doping the brick with fluorescent powder, a qualitative understanding of particle spread throughout each step of handling and analysis was able to be obtained and photographed. A second simulated brick was created and analyzed to obtain video of the processes. While the processes used to analyze drug, evidence are specific to individual laboratories, and therefore may not be accurately reflected in this work, this approach can be easily implemented by any practicing laboratory. Adoption of a visualization approach such as this by forensic laboratories can aid in identifying common processes or behaviors that contribute to drug background levels in their environment. It can also be a valuable tool for training forensic scientists on the importance of personal protective equipment, good laboratory practices, and particle transport processes. Additionally, while this study focused on the analysis of large amounts of drug evidence (approximately 1 kg bricks), this approach can be adapted to smaller evidence amounts.

2. Materials and methods

For this study, two bricks containing inert material designed to simulate drug bricks were created. The first was created using all-purpose flour with yellow Glo Germ powder (Moab, UT, USA) added to allow for visualization under black light. The second was created using mannitol with orange Glo Germ powder added. The materials used were chosen for their inertness, ability to obtain large enough quantities, and compressibility and may not fully represent all chemical properties of common street drugs. Mannitol, however, is a common cutting agent in seized drug samples. Particle size distributions for both compounds are shown in Fig. 1. The particle size distributions were measured by analyzing between 25 g and 30 g of powder using a series of sieves (cutoffs of 600 µm, 300 µm, 150 µm, 106 µm, 90 µm, 63 µm, 45 µm, and 25 µm. The sieves were vibrated for 18 min on a Gilson Performer III SS-3 (Lewis Center, OH, USA) before being weighed.

The simulated bricks were wrapped in plastic wrap and duct tape obtained from a local grocery store then packaged in plastic bags (Kapak, Minneapolis, MN, USA). The first brick was created by weighing out approximately 800 g of all-purpose flour and 4 g of yellow fluorescent powder (Glo Germ) into a large plastic bag. The bag was heat sealed and the substances were mixed, by hand, for five minutes to ensure that the fluorescent powder was well-distributed throughout the flour. A similar process was used for the second brick, containing mannitol, except that the mass of mannitol used was approximately 1000 g. Each mixture was then poured into a brick mold (Fig. 2), measuring 22 cm by 14 cm by 3.5 cm, which had been covered with three layers of plastic wrap. The mixture was compacted in the mold, by hand, and then completely wrapped in plastic wrap. A single layer of duct tape was then added to the brick followed by three additional layers of plastic wrap and two additional layers of duct tape. The brick was then packaged in a heat-sealed plastic bag in order to mimic the form in which drug evidence can be submitted.

Visualization of the process was completed with a Sony Handycam video camera and a Nikon D90 digital camera. Several UV-lights were positioned around the mock build site to facilitate illumination of the fluorescent powder. During each stage of the building process and the post-build forensic analysis, the builder/practitioner paused activities so still digital images could be taken of the brick, hands, and all other relevant surfaces. Long camera exposure times (approximately 2 s) were needed in most cases due to the limited illumination available from the UV-lights. For the second brick, the video camera was recording during the entire mock building session.

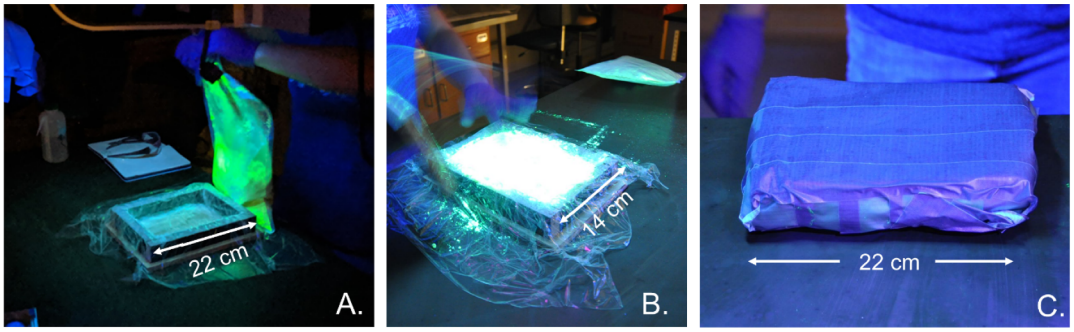
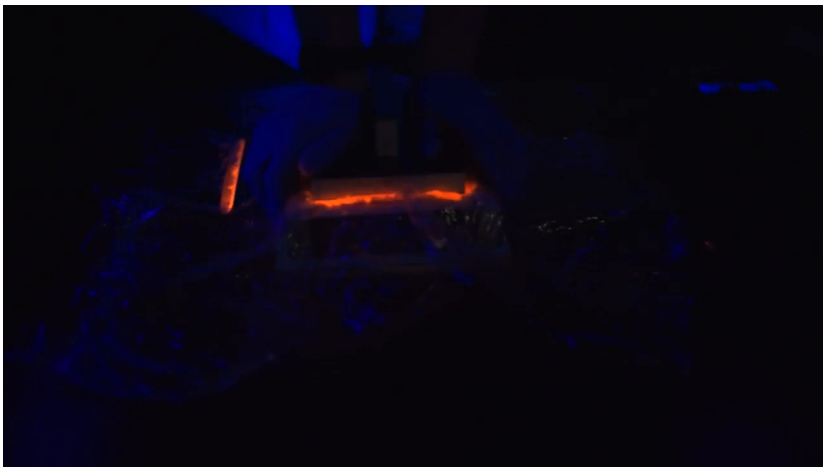


Fig. 2. Creation of the simulated heroin brick. (A.) The brick mold and flour prior to creating the brick. (B.) The compressed brick in the mold. (C.) The final, wrapped, brick. The flour / fluorescent powder mixture is the yellow fluorescing material. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

3. Results and discussion

3.1. Creation of the simulated heroin brick

Since the goal of this study was to demonstrate an approach to visualize particle spread during the forensic analysis of drug evidence, simulant bricks of inert material containing fluorescent powder were created. Creation of the bricks led to substantial particle spread in the area immediately surrounding the mold (Fig. 2B.) which was readily visible with UV-light. Substantial contamination was also observed on the gloves of the person creating the brick, as expected. Minimal external contamination of the brick itself occurred. After the brick was created and packaged, care was taken to ensure that the entire workspace was thoroughly cleaned, with wetted methanol wipes, and that no fluorescent particles were present prior to the analysis. A video of the process of the creation of the second brick can be found in the Supplemental Information (Supplemental Video 1).

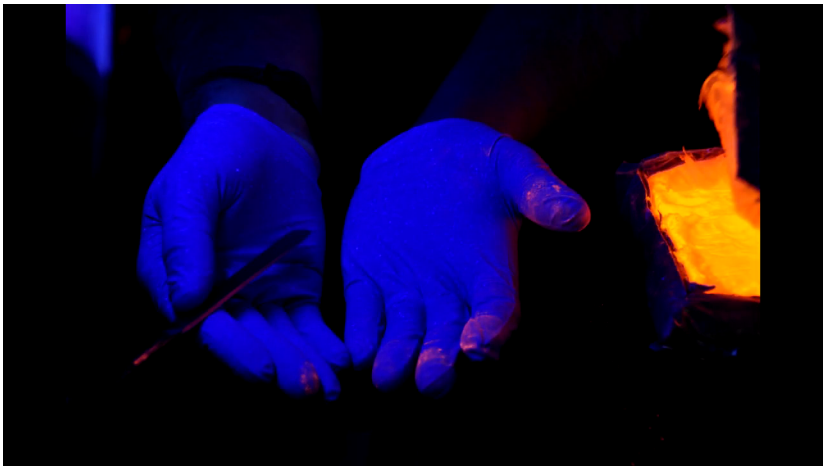


Video 1.

3.2. Analysis of the brick

Analysis of the bricks was completed in accordance with the policies of a practicing forensic laboratory. Policies vary by laboratory and therefore may not be directly translatable to other laboratories. All steps, up to analysis of the alcoholic extract by gas chromatography mass spectrometry (GC–MS), were completed. These steps included: opening of the outer submittal packaging (plastic bag), using a scalpel to open the brick, removal of the brick contents into a tared secondary plastic bag (to obtain a net weight), representative sampling of the material for chemical analysis, repackaging of the evidence, and cleaning of work surfaces. Of the two bricks that were made for this study the first was analyzed in a fume hood. The second brick was analyzed on a laboratory bench so that the entire process could be filmed.

The first step in the analysis process was unpackaging and opening of the drug evidence. During this process, the submittal packaging (plastic bag) was cut open using scissors, labeled, and the brick removed. The submittal packaging was placed outside of the hood during analysis. A scalpel was then used to cut along the edges of the brick so that the powder was visible (Fig. 3A.). The process of cutting the brick open (Supplemental Video 2) was shown to contribute to a large amount of particulate being released, especially as the plastic wrap and duct tape were pulled back. This opening process caused powder to be transferred onto both sides of the practitioner's gloves (Fig. 3B.), with higher amounts present on the glove used to pull back the packaging. The scalpel used to open the packaging (Fig. 4B.) also had a large amount of particulate on it that was concentrated along the cutout within the blade that is grasped by the handle. At this point in the analysis process, analysts should be aware that their gloves likely contain significant amounts of trace drug residue, and any subsequent surface that is touched, or item that is handled, will likely have material transferred onto it. Additionally, visual inspection of the fume hood showed fluorescent particles present across the entirety of the hood, indicating that particulate traveling at least one meter is not unexpected (the footprint of the fume hood was 70 cm by 120 cm).



Video 2.

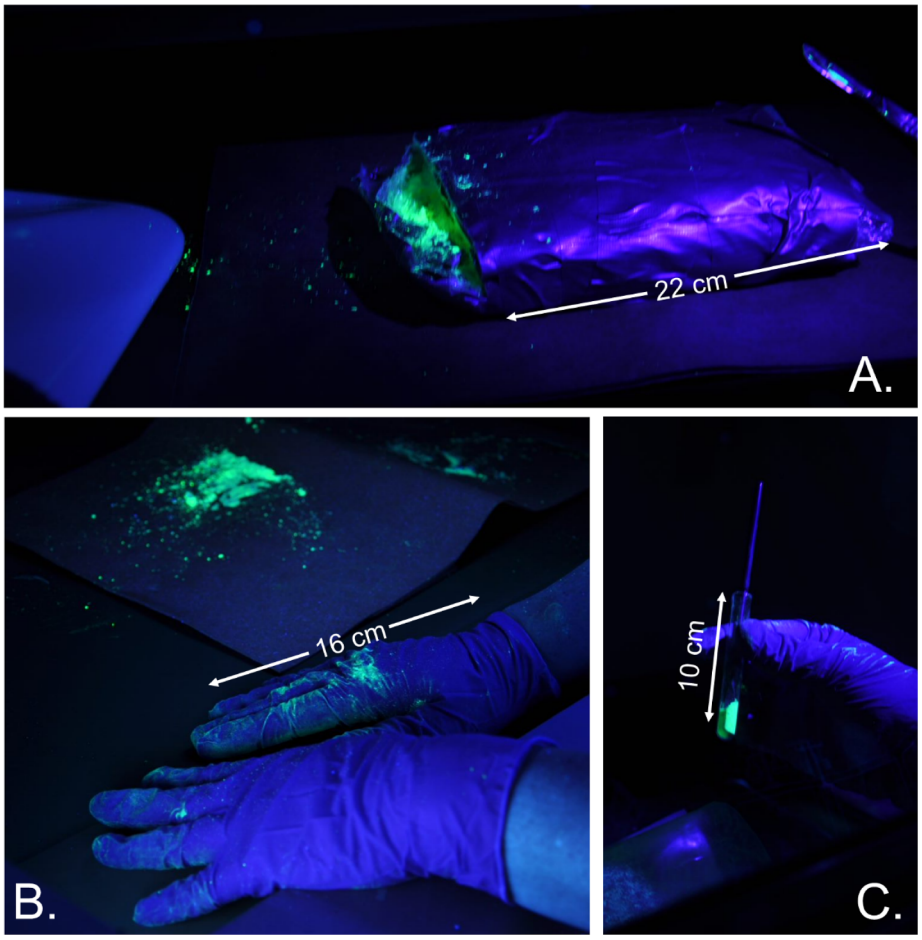


Fig. 3. Photographs from the opening and analysis of the simulant brick. (A.) The brick after it has been cut open using a scalpel. (B.) Particulate transfer onto gloves after opening the brick. (C.) Transfer of a representative sample into a glass test tube. The flour / fluorescent powder mixture is the yellow fluorescing material. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

After opening the brick, the powder was transferred to a tared, secondary, plastic bag and a net weight was obtained. Because the secondary bag was not sealed after this process, trace particulate was released during the transfer process, and was observed on surfaces surrounding the balance as well as the balance itself (Fig. 4C.) even though the powder was not poured onto or around the balance. If an analyst was required to transport opened bags between benches or across laboratories, it is possible that particulate material may settle on surfaces along the transfer route and could be further dispersed throughout the lab.

Once a net weight was obtained, the powder was sampled by coring a small hole into the brick to using a metal spatula to obtain a representative sample which was then transferred to a glass test tube. The process of obtaining the representative sample was not forceful, as the brick was not compact enough to require significant force to break. This process produced a relatively minor amount of trace particulate release

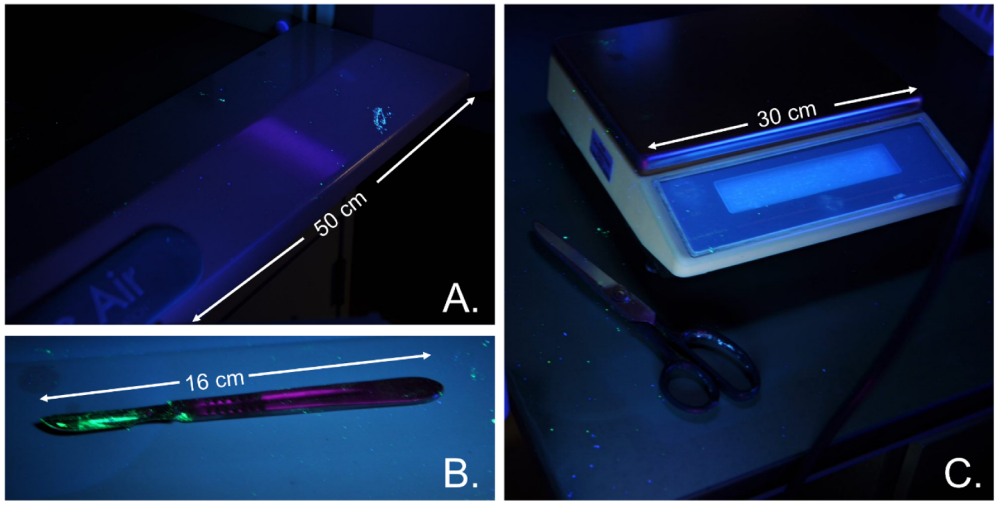


Fig. 4. Photographs from the analysis and weighing of the simulant brick. (A.) Touch transfer of particulate to the exterior of the fume hood during analysis. (B.) Scalpel used to open the simulant brick. (C.) Particulate present around and on balance after taking a net weight. The flour / fluorescent powder mixture is the yellow fluorescing material. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

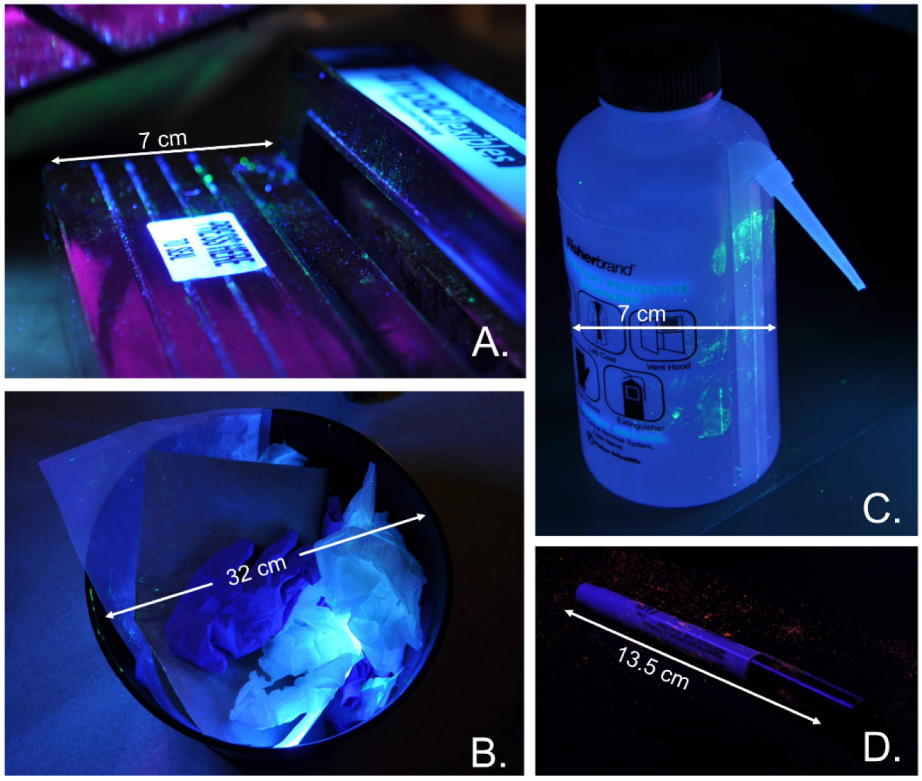


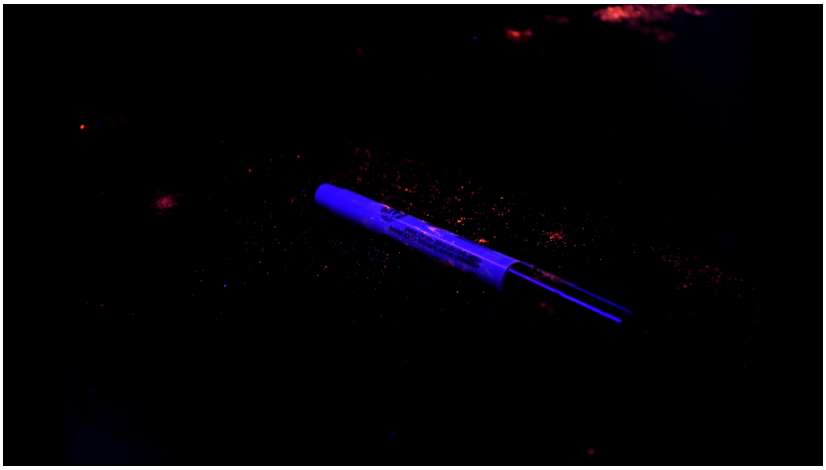
Fig. 5. Photographs from the repackaging and cleaning processes. (A.) The heat sealer after sealing the plastic bags. (B.) Residue from the fluorescent particles in and on the designated waste container and the wipes used to clean the benchtop and tools. (C.) Methanol wash bottle after cleaning. (D.) Permanent marker after analysis. The flour / fluorescent powder mixture is the yellow fluorescing material in A., B., and C. The photograph in D. is from the analysis of the second brick which used orange fluorescent powder. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

(Fig. 3C.). In the second brick analysis, the sample was transferred into a GC vial (instead of a test tube), also using a metal spatula, and the small opening of the vial caused static discharge of the powder leading to trace particulate on the rim of the vial (Fig. S1) as well as additional particulate on the exterior of the vial itself. It should also be noted that, while not pictured, trace particulate is present on the exterior or the test tube (or GC vial) and is likely attributed to handling with contaminated gloves.

Following representative sampling, the brick was repackaged. In this instance, the secondary plastic bag that the powder was transferred to was heat sealed and then packaged into the original submittal packaging (plastic bag) along with the duct tape and plastic wrap layers that originally contained the brick. The process of removing the air from the plastic bag, so it could be sealed, caused a significant release of particulate, which likely contributed to the presence of fluorescent particles throughout the fume hood. Care should be taken during this process to ensure that the opening of the bag is not facing the practitioner. Repackaging of the evidence into the original packaging was another area where trace residue was released. Given that repackaging of evidence is often not a consideration when evidence is initially packaged, fitting the evidence back into the submittal packaging can be difficult. In this case, it led to handling of the material in a fashion that caused transfer of trace residue to the exterior of the submittal packaging. The presence of trace residue on the exterior may be of concern as evidence technicians or officers who will eventually handle this packaging may not be wearing gloves. Because clear plastic bags were used in this study, it was difficult to visually capture whether the trace residue was on the exterior or interior of the bag. The second brick was therefore repackaged in an opaque foil bag to effectively capture the exterior residue. Fig. S2 shows that there is, indeed, trace residue that is transferred onto the exterior of the bag, consistent with previous studies that have demonstrated trace residue on the exterior of drug evidence [24].

The heat sealer represents another unique area where trace residue is transferred during this process (Fig. 5A.). This surface has been identified in other work as an area with elevated background levels [3]. There are likely two contributors to this process – gloves that have trace residue, and residue present on the edge of plastic bag being sealed. In both instances, these residues may be transferred onto the heat sealer during the sealing process. The contribution of both processes was evident, and can be seen in Fig. 5A., where residue is visible on the lower portion of the heat sealer (handled by a gloved hand) as well as along the plastic surrounding the heating element (which was not handled).

The final step in the analysis was cleaning of the work surfaces (Supplemental Video 3). For this, benchtop surfaces were cleaned with methanol (from a wash bottle) and wiped with absorbent wipes. Previous work has shown that methanol is effective at removing nearly all drug particulate from workbenches [25], and similar results were observed here. Methanol rinsing removed nearly all the fluorescent particulate from the fume hood workspace. It should be noted, however, that particulate was transferred into the designated waste container, as shown in Fig. 5B., and that the wipes used to clean the surface were heavily contaminated with the fluorescent material. Because of this, care should be taken by laboratory and/or janitorial staff when handling potentially contaminated waste from a drug unit.



Video 3.

Inspection of surfaces and items after cleaning revealed two additional areas where trace residue can be transferred. First, tools, writing implements, or utensils that were used during the analysis of the evidence contained easily visible levels of fluorescent particles (Fig. 4B., C., and 5D.). Presence of powder on these surfaces was likely caused from handling with gloves that had trace particulate on it. This also led to the fluorescent particulate on the exterior of the methanol wash bottle (Fig. 5C.).

Possible Strategies for Reducing Trace Particulate Transfer

Using fluorescent particles to visualize this approach to drug evidence analysis led to the identification of several steps that could be taken to reduce trace particulate transfer and, in turn, possibly reduce background levels. While some of these steps have already been implemented by laboratories throughout the country prior to this work [26–28], they represent steps that can be taken to allow a safer analysis. These steps include:

- Frequent changing of gloves during the analysis process, especially after exposure to or handling of bulk powder.
- Use of craft paper or another barrier between the lab bench and the evidence to reduce transfer onto benches and aid in cleanup, though removal of the barrier may present another opportunity for particle release.
- Minimizing the distance needed to transfer powdered material to balances to prevent particle release over a large area.
- Ensuring wash bottles are cleaned and keeping wash bottles used for casework and cleaning separate.
- Ensuring PPE is worn when handling potentially contaminated waste and minimizing disruption of potentially contaminated waste as much as possible.
- Implementation of a full-scale, regular, cleaning protocol that includes cleaning surfaces that may be overlooked or infrequently used (*i.e.*, heat sealers).
- Employing the use of clean mats at thresholds between laboratory and non-laboratory space to minimize the chance of particle spread throughout the laboratory because of material being present on shoes.
- Ensuring the submitted packaging (Kapak) is of a sufficient size for repackaging. Having to excessively handle or force evidence back into the submitted packaging could cause unnecessary disruption of powder and increased particle transfer.
- Transfer of powdered material into vials or test tubes with a sufficiently large mouth to avoid issues with static discharge. Also, electrically neutralize plastic bags prior to transferring powder.
- Ensure adequate moisture levels in the laboratory to minimize the potential for electrostatic spreading of powdered material.
- Ensuring analysts have dedicated consumables (pens, scissors, rulers, etc.) for casework that are not taken outside of the laboratory space. Also, cleaning of these items between cases.
- Taking care to not repackage evidence in the same area where evidence was handled (*i.e.*, keeping the submittal packaging off the craft paper where evidence was opened). This may reduce the transfer of residue to the exterior or the submittal packaging (which may be handled by personnel not wearing PPE).
- Being aware that having personal items (cell phones, laptops) near casework may cause non-visible, unwanted transfer of drug particulate onto these surfaces which could then be further transferred to other surfaces outside of the laboratory space.

Additionally, the National Institute of Occupational Safety and Health (NIOSH) has recently released a report evaluating practices of drug chemists handling of seized materials that contains additional suggestions for completing a safe analysis [29].

4. Conclusion

Utilization of fluorescent material and a UV-light sources present a viable method for laboratories to understand the processes they use which may contribute to drug background. The processes examined here demonstrated that handling of drug evidence by forensic chemists can lead to transfer of trace particulate onto various surfaces throughout the laboratory. Transfer of trace particulate is inevitable given most cases are bulk powders. The fact that material is transferred to other surfaces is not an indication of poor work practices – it is merely a function of the work that occurs. While the process of trace particulate transfer may not be easily demonstrated under normal laboratory settings, employing visualization tools such as those discussed here, can provide a mechanism to better understand the underlying processes. This work provides a demonstration of where trace particulate can spread to while analyzing a brick of suspected drugs and it may not be indicative of the spread in other instances. Loose powder cases may spread differently and the mass of material present, the size of the particles, and the properties of the packaging could all play a role in transfer. This visualization method, however, could be used to investigate these variables. There is also the potential for a visualization method like this to be useful to processes outside of the drug unit.

Manufacturing of homemade explosive devices generates trace levels of contamination on surfaces and could be visualized by the methods discussed here. Trace evidence, firearms, and even DNA could benefit from visualization tools such as this being used in simulated case analysis to identify procedures that may contribute to unwanted material transfer or to aid in the development, or justification, of best practices for evidence handling.

5. Disclaimer

Points of view are the authors and do not necessarily represent the official position or policies of the National Institute of Standards and Technology.

Certain commercial equipment, instruments and materials are identified in order to specify experimental procedures as completely as possible. In no case does such identification imply a recommendation or endorsement by the National Institute of Standards and Technology nor does it imply that any of the materials, instruments or equipment identified are necessarily the best available for the purpose.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.forc.2020.100232.

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