Investigating the Transfer of Drug Particulate onto Evidence Packaging During Routine Case Analysis

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Highlights

- Drug residues on evidence packaging were measured prior to and after case analysis.
- In nearly all instances, an increase in the amount of residue on the packaging was observed.
- Similar results were obtained for items repackaged in the original Kapak and in a new Kapak.
- Residue on seized drug packaging continued to be an excellent predictor of the contents.

Abstract

The presence of drug residue and drug background in a forensic context continues to be of interest for a variety of reasons ranging from its potential use as a means for presumptive identification to ensuring the safety and well-being of drug chemists. While prior work has studied the presence of these residues on laboratory surfaces and on drug evidence, the contribution of residue on the exterior of drug packaging from the analysis process itself has not yet been studied. This work aims to qualitatively and quantitively identify what, if any, effect the analysis of drug evidence has on the drug residue levels on the exterior of the evidence packaging. Using wipe collection techniques, samples from the exterior of drug evidence packaging were taken prior to opening cases and after repackaging to measure changes in residue composition and mass. A total of 64 submissions were analyzed, and an increase in drug residue mass was observed 85.5 % of the time. After analysis and repackaging, 95 % of packages had detectable drug residue on their exterior even though some of the cases were repackaged into new bags. Drug residue masses on the exterior of drug packaging were found to be as high as tens of micrograms. The presence of drug residue on the exterior of drug evidence packaging is expected given the collection and analysis procedures, therefore potential ways to minimize these levels are currently being studied. The presence of these residues is an important factor to consider when developing protocols for the entire evidence handling process and its impact on personnel – from evidence handling technicians to crime scene technicians to submitting officers.

Keywords: Drug Evidence; Residue; Background; Exposure; Opioids; Safety; DART-MS

Introduction

Given the potency of many emerging drugs and novel psychoactive substances, the health and safety of forensic practitioners, evidence handling technicians, crime scene technicians, and others in the forensic analysis chain continues to be of major concern. While there has been little reported in terms of exposure of forensic chemists to controlled substances, recent reports have identified that such exposure can occur[1]. Similar reports relating to clandestine laboratory chemists and emergency responders also highlight the potential exposure risks that emerging drugs, such as synthetic opioids, present[2,3]. One potential route, or indicator, of exposure is residual drug particulate that can be found on surfaces and items throughout the laboratory. A number of studies have shown that drug residues are ubiquitous in drug chemistry units of forensic laboratories[4–6] and in evidence handling areas of police stations[7,8]. Other studies, which have visualized the evidence handling process, have demonstrated that aerosolization of drug particulate while handling powders is one of the main drivers for the presence of residue on surfaces[9,10]. Aerosolization of particulates is a problem that is not unique to forensic drug

chemistry and has been demonstrated in other fields such as pharmaceutical production[11], medicine[12–14], and food science[15].

Understanding the presence and prevalence of drug background in a forensic environment, as well as the processes that may contribute to or prevent accumulation of residue, is critical to better inform the development of best practices. Several best practices have been established to increase safety of drug chemists and evidence handling techniques which outline ways to prevent exposure through inhalation or accidental contact. Suggested best practices always recommend that personnel wear gloves when handling drug evidence, regardless of whether the evidence is open or sealed. Wearing gloves when handling open drug evidence is a logical practice, but the use of gloves when handling sealed evidence may be less intuitive. Previous work has demonstrated that, frequently, drug residue is present even on the outer evidence packaging and may have been transferred onto the packaging through contaminated environments in which the evidence was packaged[16].

The study described here looks to take previous work one step further and examine whether or not opening and analyzing the drug evidence of a case in a forensic laboratory contributes to the drug residue on the outer evidence packaging. To do so, wipe samples of drug evidence packaging were taken prior to opening submissions and after re-packaging. Qualitative and quantitative measurements of the wipes were then made to establish the identities and quantities of drug residues on the exterior of the evidence packaging to better understand whether or not the act of opening, analyzing, and repackaging evidence leads to increases in the number and amounts of drugs present. The goal of this study was to provide tangible data to support the recommendation of glove use by those who are handling sealed drug evidence while also providing baseline measurements to better inform future studies focused on possible processes to reduce the transfer of residue during the analysis process.

Materials and Methods

Sampling Collection and Preparation

Collection of wipe samples from actual drug evidence submission was completed at the Vermont Forensic Laboratory and the Maryland State Police Forensic Sciences Division. Since the goal of this effort was to identify what, if any, drug residue is transferred onto the evidence packaging during the forensic analysis process, a sequential wiping process, outlined in Figure 1, was used. Dry meta-aramid wipes (DSA Detection, North Andover, MA, USA) were used for sample collection and stored, individually, in manilla envelopes after collection. Dry wipes were used to avoid smearing or dissolving important markings or signatures on the evidence packaging. Collection was completed using a unidirectional wiping pattern with a firm force.

Samples

A total of 64 individual evidence submissions were analyzed. The outer packaging for all submissions was a Kapak bag, and all submissions were repackaged into a Kapak bag. Two different repackaging protocols were used, depending on the laboratory, with submissions being repackaged into a new Kapak bag (n = 46) or being repackaged into the original Kapak bag (n = 18). Most submissions (n = 48) consisted of a single item, though 14 submissions had two items within the submission and two submissions had three items resulting in a total of 82 individual items and 82 inner packages. Of those items, the majority (n = 52) of the inner packaging were plastic

bags, with an additional 22 glassine bags, three foil bags or folds, two suboxone packets, one paper bag, one screw cap vial, and one piece of currency. All but three of the items contained powder. Two items contained suboxone strips and one item contained residue on currency.

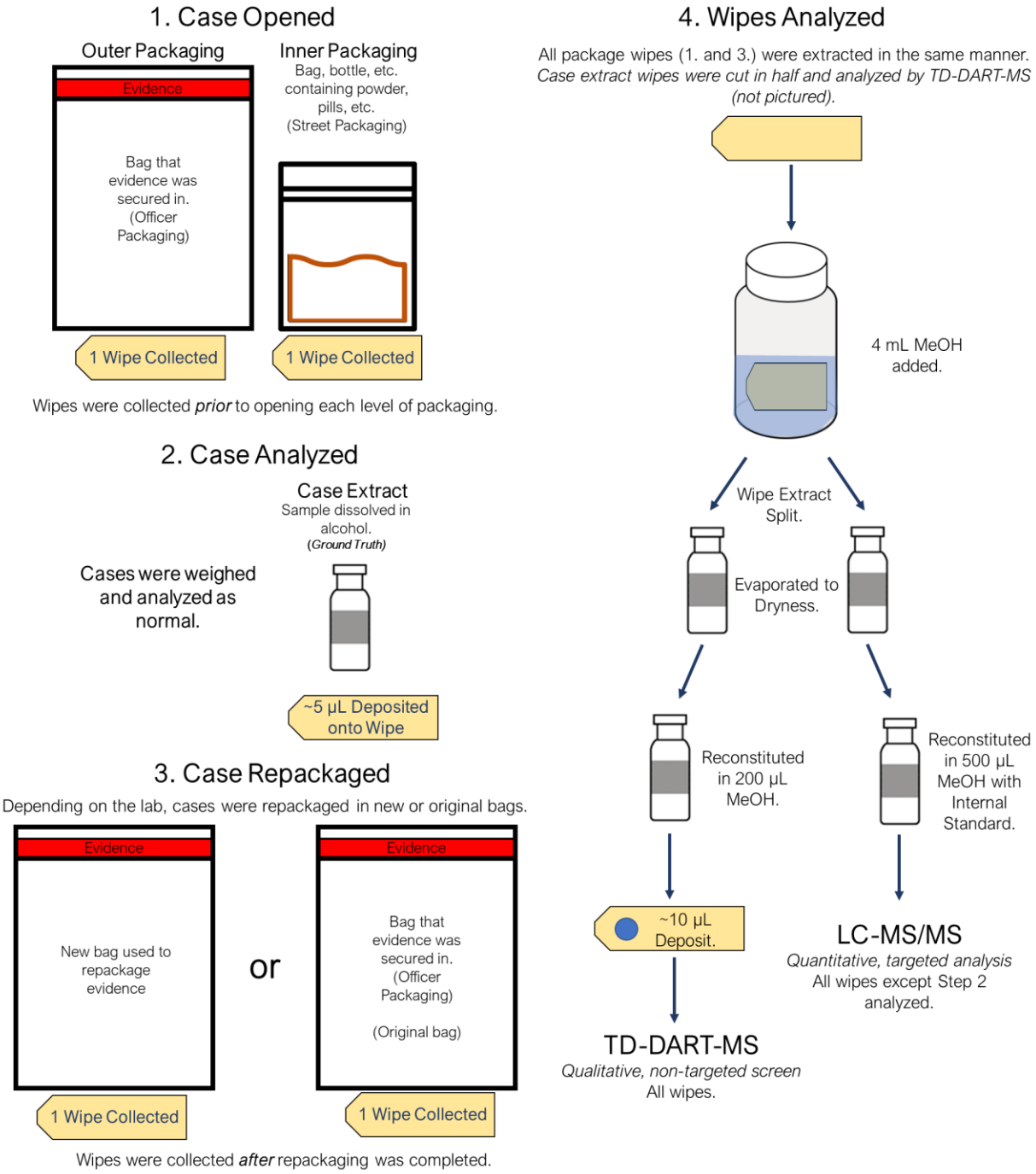

Figure 1. Schematic of the sample collection and analysis procedure used for this study. Abbreviations for thermal desorption direct analysis in real time mass spectrometry (TD-DART-MS) and liquid chromatography tandem mass spectrometry (LC-MS/MS) are used.

For each case the following protocol was used. When submitted evidence was to be analyzed, the chemist first wiped the outer packaging, defined as the Kapak bag that the evidence was submitted in, and stored the wipe in a

marked manilla envelope. The chemist then opened the outer packaging as they normally would and removed the contents, which consisted of one or more inner packages (glassine envelopes, pill bottles, etc.). To gain a further understanding of the ability of inner packaging residue to predict the drug contents, as shown in previous work[16], each inner package was also wiped by the chemist prior to opening. Separate wipes were used for each inner package and stored individually in marked manilla envelopes. Following this step (Figure 1, Step 1), chemists analyzed their cases as they normally would. When samples were prepared for analysis by gas chromatography mass spectrometry (GC-MS) an approximately 5 µL aliquot of the evidence extract was placed on another wipe to provide a ground truth sample for analysis (Figure 1, Step 2). Once the chemist completed their analyses, the items were repackaged following each laboratory's protocols. For one laboratory, this involved re-packaging evidence in the original Kapak bag that the evidence was submitted in. The other laboratory repackaged items into a new Kapak bag. Once repackaging was completed, a final wipe of the outer packaging was taken, with the chemist using new gloves, and stored individually in a marked envelope (Figure 1, Step 3). Once the wipes were collected, they were extracted and analyzed using a combination of thermal desorption direct analysis in real time mass spectrometry (TD-DART-MS) and liquid chromatography tandem mass spectrometry (LC-MS/MS) for qualitative and quantitative purposes, respectively.

Extraction of Wipes

All outer packaging wipes were extracted in the same manner (Figure 1, Step 4), which first involved placing wipes in 10 mL glass vials and adding 4 mL methanol (Chromasolv-grade, Millipor-Sigma, St. Louis, MO, USA). After vortexing the vials at 50 Hz (3000 rpm) for 30 s, the 4 mL was split into two 2 mL glass vials, one for qualitative and one for quantitative analysis. Both vials were evaporated to dryness by leaving the vials open in a fume hood for several days. Once evaporated, 200 µL of methanol was added to the qualitative (TD-DART-MS) vial which was capped and vortexed. A 10 µL aliquot was then pipetted onto a new meta-aramid wipe for analysis by TD-DART-MS. For samples with visible residue after evaporation, a deposit of 1 µL to 2 µL was used to prevent overloading the thermal desorption chamber. For the quantitative extract, once evaporated it was reconstituted in 500 µL of methanol containing deuterated internal standards (cocaine-d3, fentanyl-d5, heroin-d9, and methamphetamine-d5). Vials were capped, vortexed, and then loaded onto the autosampler for LC-MS/MS analysis. The wipe containing the evidence extract from Step 2 (Figure 1) was not extracted prior to qualitative analysis.

Qualitative TD-DART-MS Analysis

TD-DART-MS, which is described in detail elsewhere[17], was used as a non-targeted, qualitative screening tool and was chosen as it has excellent sensitivity, is rapid, and allows for direct analysis of wipes. The TD-DART-MS system used incorporated a JEOL JMS-T100LP mass spectrometer (JEOL USA, Peabody, MA, USA) coupled with a DART-SVP ion source (IonSense, Saugus, MA, USA), and a custom thermal desorption unit. All analyses were completed in positive ionization mode with a thermal desorber temperature of 265 ºC, a nitrogen DART gas stream temperature of 400 ºC, a DART grid electrode voltage of +100 V, and a Vapur flow rate of approximately 4 L min^{-1}. Mass spectrometer settings included an orifice 1 voltage of +20 V, a ring lens and orifice 2 voltage of +5 V, an orifice temperature of 100 ºC, and a peaks voltage (RF ion guide) of +800 V. A mass spectral scan range of *m/z* 80

to *m/z* 600 was used with a 2 scan s^{-1} scan rate. Polyethylene glycol 600 (PEG-600) was used as an *m/z* calibration compound.

Analysis of the packaging samples (Figure 1, Steps 1 and 3) was completed by inserting the wipe containing a dried aliquot of the extract directly into the thermal desorber for 3 s to 5 s, while the ground truth evidence extract (Figure 1, Step 2), was analyzed directly, without the additional extraction described in Step 4. Identification of compounds of interest in the resulting mass spectra was accomplished by searching the mass spectra against an in-house search list of over 700 compounds using Mass Mountaineer (Fineview, NY, USA). Relevant search settings included a tolerance of ±0.005 Da and a peak identification threshold of 2 % relative intensity.

Quantitative LC-MS/MS Analysis

The wipe extract prepared for quantitative analysis was analyzed by LC-MS/MS using a procedure that has been described in detail elsewhere[4]. Measurements for six of the observed drugs (cocaine, fentanyl, heroin, MDMA, methamphetamine, and oxycodone) were obtained. Analysis was completed using a Thermo UltiMate 3000 liquid chromatography system (Thermo Fisher Scientific, Waltham, MA, USA) coupled to a Sciex 4000 QTrap mass spectrometer (Sciex, Framingham, MA, USA). The LC-MS/MS method used here was identical to that described previously[4] with the exception of only targeting the six drugs of interest. The resulting raw quantitative values were then adjusted to estimate the total amount of material present on the packaging using the following assumption: the collection efficiency of the wipe was approximately 33 % [18] and therefore the amount of material on the packaging was approximately three-times the value obtained after doubling to account for the initial 4 mL extract being split into two vials for the separate analyses.

Results & Discussion

Qualitative Results

Analysis of the outer packaging wipes taken prior to opening the evidence (Table 1) showed that detection of at least one of the drugs in the evidence extract was present on the exterior of the outer packaging roughly 80 % of the time. This was significantly higher than was reported in a previous study where agreement was only 32 %[16]. This may have been driven by the higher fraction of cocaine cases in this dataset compared to the previous dataset. These cases typically have higher residue levels then other drugs, increasing the likelihood for detection. For both cases where no controlled substances were found in the evidence extract, the wipes of the outer packaging were also found to not contain any controlled substances. One case had only cocaine present on the exterior of the packaging, but a different drug was found in the evidence extract itself, which is not unexpected given the prevalence of cocaine in the environment[8]. Five of the six cases that had a drug present on the outer packaging that matched at least one of the drugs present in the evidence extract also had cocaine present on the exterior, however, in three of these instances, cocaine was present in an additional item submitted for that case. Finally, nine of the cases that did contain drugs in the evidence extract had no detectable levels on the exterior of the outer packaging prior to opening the case.

Table 1. Summary of the results obtained from the qualitative analysis of the outer drug evidence packaging pre- and post- case analysis wipes. Note that for some cases there were multiple submissions of items from the same case which were repackaged into a single Kapak.

Extract	Outer Packaging	Pre-Opening Occurrence	Post-Repackaging Occurrence
Drug(s) Detected	Same Drug(s) Detected	81.3 % (n = 52)	93.3 % (n = 56)
Drug(s) Detected	Different Drug(s) Detected	1.6 % (n = 1)	0 % (n = 0)
Drug(s) Detected	No Drug Detected	14.1 % (n = 9)	5 % (n = 3)
No Drugs Detected	No Drug Detected	3.1 % (n = 2)	1.6 % (n = 1)

As shown in Table 1, a substantial increase in the detection of case-related drugs was seen on the post-repackaging wipes (Row 1, increase from 81.3 % to 93.3 %). All cases that had a matching drug present on the pre-opening wipe also had the same drug present on the post-repackaging wipe. As discussed in the following section, nearly all of those instances also saw increases in the amount of material present, indicating that the drug residue was not solely attributable to residue remaining on the packaging after the initial wipe prior to opening the packaging. In ten of the instances, samples that contained drugs had different or no drugs found on the pre-opening wipe (n = 1 and n = 9, respectively). Both of these values decreased in the post-repackaging wipes dataset (n = 0 and n = 3, respectively), indicating that case-specific drugs were being transferred onto the Kapaks. It should be noted that in four instances of the repackaging using new Kapak bags, multiple items from the same case that were submitted separately were combined into a single post-analysis Kapak, leading to a total of 60 post-repackaging wipes instead of 64. There appeared to be no obvious difference in terms of the residue present after repackaging between those repackaged in the original Kapak versus those repackaged into a new Kapak. Transfer of buprenorphine residue from the analysis of suboxone strips was minimal. For both samples, no buprenorphine was present on the pre-opening wipes and only one post-repackaging wipe produced a low-intensity peak for buprenorphine. Supplemental Table 1 shows the full TD-DART-MS results for all 64 of the submissions.

Quantitative Results

In addition to looking at the qualitative presence or absence of drugs on the evidence packaging, quantitative information was also obtained for six of the compounds which an LC-MS/MS method existed for in-house (cocaine, fentanyl, heroin, MDMA, methamphetamine, and oxycodone). Wipes of the outer evidence packaging taken prior to opening (Figure 1, Step 1) highlighted that drug residue is present on the majority of evidence packaging prior to analysis. Out of the 62 submissions that contained one or more controlled substances (two submissions contained no controlled substances), 46 submissions (≈74 %) had quantifiable levels of at least one of the drugs present in the case. The amount of material recovered was typically sub- to single microgram in quantity with average recoveries ranging from 0.06 µg (oxycodone) to 1.43 µg (heroin). Ten packages had initial masses of greater than 1 µg of drug present – four instances each of cocaine and heroin, and two instances of methamphetamine – with a maximum of 15.60 µg of heroin recovered off one package. Full quantitative data for all wipes can be found in Supplemental Table 2.

Table 2. Summary of the results obtained from the quantitative analysis of the pre-opening and post-repackaging wipes. Both overall values and values broken out by repackaging protocol are shown. The increase or decrease of each drug on a package was treated as an individual instance. Instances where a drug was present on the packaging but not actually in the case are not included in this dataset. Reported values were adjusted to incorporate a 33 % collection efficiency.

	# of Times Amount Decreased	# of Times Amount Increased	% of Times Amount Increased	Minimum Increase (µg)	Maximum Increase (µg)	Mean Increase (µg)
Overall (n=66)	9	57	86.4 %	0.03	49.47	4.28
New Kapak (n=50)	4	46	92.0 %	0.03	49.47	3.93
Original Kapak (n=16)	5	11	68.8 %	0.45	26.07	5.71

Wipes taken after repackaging showed, on average, a two- to three-fold increase in the amount of material when compared to the pre-analysis wipes. Post-repackaging wipes had average recovered masses above 1 µg for cocaine (2.87 µg), heroin (8.05 µg), methamphetamine (8.72 µg), and oxycodone (10.00 µg). As shown in Table 2, for 86.4 % of all instances (individual drugs detected in a sample) an increase in recovered mass between the pre-opening wipe and post-repackaging wipe was observed. The overall average increase in amount of recovered material was 4.28 µg, with a maximum increase of 49.47 µg. Only nine of the instances (13.6 %) showed a decrease in amount of material – which would be attributed to either use of new Kapak that did not have residue transferred on it or a reduction in mass in the post-repackaging wipe due to the removal of residue with initial pre-opening wipe. Surprisingly, repackaging of evidence into a new Kapak did not lead to a reduction in residue on the packaging exterior as may have been expected (Table 2). Potential reasons for this observation are discussed in detail below. The samples repackaged into a new Kapak had a slightly higher percentage of samples that saw an increase in drug amounts, while 69 % of the samples that were repackaged into the original Kapak showed an increase. This observation may be due to the smaller sample size for the original Kapak samples (n = 16 compared to n = 50) or may be due to variations in analysis protocols at both laboratories.

Use of Inner Packaging Residue to Predict Contents

Since wiping of the outer evidence packaging was being completed for the study, it was decided that the inner packaging (bag, bottle, street packaging, etc.) would also be wiped to determine if the ability to accurately predict the contents based on the residue aligned with previously published work[16]. As with the outer packaging wipes, the inner packaging wipes were analyzed both qualitatively and quantitatively and a positive result was defined as the presence of at least one of the drugs in the case present in the residue on the exterior of the inner packaging. While the full results can be found in Supplemental Table 3 (qualitative, TD-DART-MS) and Supplemental Table 4 (quantitative, LC-MS/MS), summary results are presented in Tables 3 and 4. In total,74 of the 82 inner packages that were wiped had at least one drug present that agreed with the evidence contents (90.2 % of samples), and the two samples that contained no controlled substances within the evidence sample had no drug residues on them (2.4 % of samples), leading to an overall accuracy of 92.7 %. This value is almost identical to previous work which found an overall accuracy of 92 %, and had just over twice the population size (n = 191)[16]. Six false negatives were found within the samples – instances where a drug was present in the evidence extract, but no residue was detected on the wipe using TD-DART-MS with two of those instances being the suboxone strips, one methamphetamine submission, two heroin submissions, and one heroin and fentanyl submission. Additionally, as expected, and as shown in previous work[16], the presence of cocaine on many of the inner packaging wipes was found even if cocaine was not present in the case – which may be attributable to environmental background from where the evidence was seized.

Table 3. Summary of the results obtained from the qualitative analysis of the inner packaging.

Extract	Inner Packaging	Result Type	Occurrence
Drug(s) Detected	Same Drug(s) Detected	True Positive	90.2 % (n = 74)
Drug(s) Detected	Different Drug(s) Detected	False Positive	0 % (n = 0)
No Drug Detected	Drug(s) Detected	False Positive	0 % (n = 0)
Drug(s) Detected	No Drug Detected	False Negative	7.3 % (n = 6)
No Drug Detected	No Drug Detected	True Negative	2.4 % (n = 2)
		Overall Accuracy:	**92.7 %**

As with the qualitative results, the quantitative results (Table 4) also showed good agreement with previous findings. Average amounts of material, after adjusting for the 33 % collection efficiency[18], ranged from single to tens of micrograms per sample. Heroin, as with previous work[16], had the highest amounts of material, with a maximum amount of over half a milligram present on one of the inner packages. Given the fact that fentanyl is typically heavily cut in street samples, it was expected that it would have the lowest amount, on average, though amounts as high as 33 µg were found. These results, compounded with previous findings, highlight the need for cautious handling of evidence to prevent potential unintentional exposure through residues.

Table 4. Summary of the results obtained from the quantitative analysis of the inner drug evidence packaging. The values reported here assume that the collection efficiency of the meta-aramid wipe was 33 %.

	# of Samples	Average Amount on Packaging (µg)	Minimum Amount on Packaging (µg)	Maximum Amount on Packaging (µg)
Cocaine	43	1.93	0.03	19.53
Fentanyl	21	2.59	0.03	32.88
Heroin	24	46.96	0.12	591.00
MDMA	1	4.95	N/A	N/A
Methamphetamine	5	11.46	0.24	28.00
Oxycodone	1	18.57	N/A	N/A

Conclusions

The most important conclusion drawn from these studies was that the process of opening, analyzing, and repackaging drug evidence led to an increase in residue on the outer packaging. This increase was likely unavoidable given the routine analysis process. The growing body of research on drug background and the processes that contribute to it highlights the inherent risks of handling dangerous powders. Simply opening a plastic or wax-paper bag containing powder will release particulate into the air, allowing it to settle on nearby surfaces. Instead of trying to eliminate the presence of residue on evidence packaging, a more practical goal would be to identify the practices that tend to contribute to or prevent the accumulation of residue and develop a best practice aimed at achieving the lowest levels reasonably obtainable. Identifying these practices are the focus of ongoing work and include identifying when, and where, to store the original or new Kapak bags, whether changing gloves prior to re-packaging would lower residue levels, and what other cleaning and handling practices could reduce residue levels. Alternatively, one could look at ways to clean packaging after analysis, but the identified approaches would need to be rapid and not interfere with items such as signatures, markings, and evidence tape that may be present.

The results of this work also highlight the need for situational awareness beyond drug chemists. Evidence handling technicians, crime scene technicians, submitting officers, and those further down the evidence handling chain should also be aware that there is a high probability the packaging they are handling is contaminated with drug residue. This type of awareness may prompt increased used of personal protective equipment, namely gloves, to prevent accidental exposure. Residue present in storage containers, which can accumulate from transfer of residue off evidence packaging is another area where increased awareness is likely beneficial. There are also potential questions that could arise with short term and long-term storage of these materials as well.

Overall, this work demonstrated that trace drug residues can be transferred onto the outer evidence packaging during the case analysis process. There was no clear benefit in repackaging of evidence in the original Kapak bag or a new Kapak, though this may be a function of how, when, and where evidence gets repackaged. Levels of controlled substances on the exterior of the outer bags typically were in the sub-microgram to single microgram range, though tens of micrograms were found in some instances. Collection of residues from the inner packaging showed good agreement with previous work and again highlight the potential to leverage trace residue for presumptive screening, especially for the presence of opioids for triaging of evidence. While current efforts are focusing on identifying best practices to minimize the transfer of drug residue to evidence packaging, this work provides another piece to the growing body of drug background research.

Disclaimer

Certain commercial products are identified in order to adequately specify the procedure; this does not imply endorsement or recommendation by NIST, nor does it imply that such products are necessarily the best available for the purpose.

Certain commercial products are identified in order to adequately specify the procedure; this does not imply endorsement or recommendation by Maryland State Police, nor does it imply that such products are necessarily the best available for the purpose.

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Supplemental Information

Table S1. Qualitative TD-DART-MS results for the wipes obtained from the outer packaging prior to opening and after repackaging. Note that items from the same case share a post-repackaging result as they were re-packaged together.

Case #	Repackaging	Contents	TD-DART-MS Result (Pre-Opening Wipe)	TD-DART-MS Result (Post-Repackaging Wipe)
1	New	Cocaine	Cocaine	Cocaine
2	New	Fentanyl, Heroin	No Drugs Detected	Fentanyl, Heroin
3	New	Cocaine	Cocaine	Cocaine
4	New	Cocaine	Cocaine	Cocaine
5	New	Cocaine, Heroin, 4-ANPP	Cocaine	Cocaine, Heroin
	New	Cocaine	Cocaine	
6	New	Fentanyl, Heroin, 4-ANPP	No Drugs Detected	Heroin
7	New	Heroin	Heroin	Heroin
8	New	Cocaine, Fentanyl, Heroin	Cocaine, Heroin	Fentanyl, Heroin
9	New	Fentanyl, 4-ANPP	No Drugs Detected	No Drugs Detected
10	New	Cocaine	Cocaine	Cocaine
11	New	Heroin	Cocaine, Heroin	Cocaine, Heroin
	New	Cocaine	Cocaine	
	New	No Controlled Substances	No Drugs Detected	
12	New	Cocaine	Cocaine	Cocaine, Fentanyl
	New	Fentanyl	Cocaine, Fentanyl	
13	New	Cocaine, Fentanyl, Heroin, 4-ANPP	Cocaine, Fentanyl, Heroin	Cocaine, Fentanyl, Heroin
	New	Heroin	Cocaine, Fentanyl, Heroin	
14	New	Cocaine	Cocaine	Cocaine
15	New	Cocaine	Cocaine	Cocaine
16	New	Cocaine	Cocaine	Cocaine
17	New	Methamphetamine	No Drugs Detected	No Drugs Detected
18	New	Methamphetamine	Methamphetamine	Methamphetamine
19	New	Fentanyl, Heroin	No Drugs Detected	Fentanyl, Heroin
20	New	Fentanyl, Heroin, Tramadol	Heroin	Fentanyl, Heroin, Tramadol
21	New	Fentanyl, Heroin, Tramadol	Heroin	Fentanyl, Heroin, Tramadol
22	New	MDMA	MDMA	MDMA
23	New	Heroin	Heroin	Heroin
24	New	Fentanyl, Heroin	Fentanyl, Heroin	Fentanyl, Heroin
25	New	Heroin, Fentanyl, 4-ANPP, Codeine, Ketamine	Heroin	Fentanyl, Heroin
26	New	Heroin	Heroin	Heroin
27	New	Fentanyl, Heroin, 4-ANPP	Heroin	Fentanyl, Heroin
28	New	Cocaine	Cocaine	Cocaine
29	New	Methamphetamine	Methamphetamine	Methamphetamine
30	New	Cocaine	Cocaine	Cocaine
31	New	Cocaine	Cocaine	Cocaine
32	New	Cocaine	Cocaine	Cocaine
33	New	Fentanyl, 4-ANPP	No Drugs Detected	Fentanyl
34	New	Methamphetamine	Methamphetamine	Methamphetamine
35	New	No Controlled Substances	No Drugs Detected	No Drugs Detected
36	New	Cocaine	Cocaine	Cocaine
37	New	Cocaine	Cocaine	Cocaine
38	New	Cocaine	No Drugs Detected	Cocaine
39	New	Cocaine	Cocaine	Cocaine
40	New	Cocaine	Cocaine	Cocaine
41	New	Cocaine	Cocaine	Cocaine
42	Original	Cocaine	Cocaine	Cocaine
43	Original	Cocaine	Cocaine	Cocaine
44	Original	Cocaine	Cocaine	Cocaine
45	Original	Eutylone	Eutylone	Eutylone, Cocaine
46	Original	Fentanyl, Heroin, 4-ANPP	Fentanyl	Fentanyl
47	Original	Cocaine	Cocaine	Cocaine
48	Original	Fentanyl, 4-ANPP	Cocaine	Cocaine, Fentanyl
49	Original	Cocaine	Cocaine	Cocaine
50	Original	Buprenorphine	No Drugs Detected	No Drugs Detected
51	Original	Oxycodone	Oxycodone	Oxycodone
52	Original	Cocaine	Cocaine	Cocaine
53	Original	Cocaine	Cocaine	Cocaine
54	Original	Cocaine, Fentanyl, 4-ANPP	Cocaine, Fentanyl	Cocaine, Fentanyl
55	Original	Buprenorphine	No Drugs Detected	Buprenorphine

56	Original	Cocaine, Fentanyl	Cocaine, Fentanyl	Cocaine, Fentanyl
57	Original	Methamphetamine, MDMA	Cocaine, Methamphetamine	Cocaine, Methamphetamine, MDMA
58	Original	Cocaine	Cocaine, Methamphetamine	Cocaine
59	Original	Fentanyl, Heroin, 4-ANPP, Etizolam, Deschloroetizolam	Cocaine, Fentanyl	Cocaine, Fentanyl, Etizolam

Table S2. Quantitative LC-MS/MS results for the wipes obtained from the outer packaging prior to opening and after repackaging. Abbreviations for the drugs include C = cocaine, F = fentanyl, H = heroin, D = MDMA, M = methamphetamine, and O = oxycodone. The values presented here include the assumed 33 % collection efficiency for the wipes. Note that items from the same case share a post-repackaging result as they were re-packaged together.

Case #	Repack.	Contents	LC-MS/MS Result (µg) (Pre-Opening Wipe)						LC-MS/MS Result (µg) (Post-Repackaging Wipe)					
			C	F	H	D	M	O	C	F	H	D	M	O
1	New	Cocaine	0.63						1.35					
2	New	Fentanyl, Heroin								0.06	0.36			
3	New	Cocaine	0.39						12.9					
4	New	Cocaine	0.33						2.25					
5	New	Cocaine, Heroin, 4-ANPP	0.09						0.15		1.17			
	New	Cocaine	0.06											
6	New	Fentanyl, Heroin, 4-ANPP									1.74			
7	New	Heroin			0.06						5.37			
8	New	Cocaine, Fentanyl, Heroin			0.36					0.03	14.58			
9	New	Fentanyl, 4-ANPP												
10	New	Cocaine							0.57					
11	New	Heroin	0.03		0.03				0.15		49.5			
	New	Cocaine	0.09		0.03									
	New	No Controlled Substances												
12	New	Cocaine	3.15						1.74	0.75				
	New	Fentanyl	2.67											
13	New	Cocaine, Fentanyl, Heroin, 4-ANPP	0.27	0.03	1.20				4.74	4.14	23.94			
	New	Heroin	0.27	0.75	15.6									
14	New	Cocaine	0.12						0.93					
15	New	Cocaine	0.12						1.14					
16	New	Cocaine	0.12						1.38					
17	New	Methamphetamine												
18	New	Methamphetamine											0.12	
19	New	Fentanyl, Heroin								0.12	4.41			
20	New	Fentanyl, Heroin, Tramadol			0.03					0.63	3.33			
21	New	Fentanyl, Heroin, Tramadol			0.06					0.21	3.39			
22	New	MDMA				0.15						0.42		
23	New	Heroin			0.84						2.43			
24	New	Fentanyl, Heroin			1.86					0.66	13.5			
25	New	Fentanyl, Heroin, 4-ANPP, Codeine, Ketamine			1.08					0.24	1.41			
26	New	Heroin			0.27						1.59			
27	New	Fentanyl, Heroin, 4-ANPP			0.09					0.15	1.23			
28	New	Cocaine	0.03						0.87					
29	New	Methamphetamine					10.74						30.33	
30	New	Cocaine	0.03											
31	New	Cocaine							0.03					
32	New	Cocaine							0.12					
33	New	Fentanyl, 4-ANPP								0.27				
34	New	Methamphetamine					7.14						11.79	
35	New	No Controlled Substances												
36	New	Cocaine	7.14						0.99					
37	New	Cocaine	0.09						0.54					
38	New	Cocaine							2.04					
39	New	Cocaine	0.12						0.24					
40	New	Cocaine	0.57						0.06					
41	New	Cocaine	0.18						0.18					
42	Original	Cocaine	0.60						7.56					
43	Original	Cocaine	0.54						2.10					
44	Original	Cocaine	0.36						26.43					
45	Original	Eutylone												

46	Original	Fentanyl, Heroin, 4-ANPP			0.06									
47	Original	Cocaine	0.84						11.25					
48	Original	Fentanyl, 4-ANPP	0.52						0.31	0.84				
49	Original	Cocaine	1.56						2.01					
50	Original	Buprenorphine												
51	Original	Oxycodone						0.06						10.26
52	Original	Cocaine	0.78						3.36					
53	Original	Cocaine												
54	Original	Cocaine, Fentanyl, 4-ANPP	0.15	0.03					1.56					
55	Original	Buprenorphine												
56	Original	Cocaine, Fentanyl	0.84						0.27					
57	Original	Methamphetamine, MDMA	0.24						0.27				0.96	
58	Original	Cocaine	0.09		0.87		0.30		1.50	0.18	0.78		0.39	
59	Original	Fentanyl, Heroin, 4-ANPP, Etizolam, Deschloroetizolam	0.12	0.15	0.42				0.36					

Table S3. Qualitative TD-DART-MS results from the inner packaging wipes.

Case #	Item #	Packaging Type	Contents	TD-DART-MS Result
1	1	Plastic	Cocaine	Cocaine
2	1	Glassine	Heroin	Cocaine
	2	Glassine	Fentanyl, Heroin	Fentanyl
3	1	Plastic	Cocaine	Cocaine
4	1	Plastic	Cocaine	Cocaine
5	1	Plastic	Cocaine, Heroin, 4-ANPP	Cocaine
	2	Plastic	Cocaine	Cocaine
6	1	Glassine	Fentanyl, Heroin, 4-ANPP	Fentanyl, Heroin
7	1	Plastic	Heroin	No Drugs Detected
	2	Glassine	Heroin	Heroin
8	1	Foil	Cocaine, Fentanyl, Heroin	Fentanyl, Heroin
9	1	Plastic	Fentanyl, 4-ANPP	Fentanyl
10	1	Plastic	Cocaine	Cocaine
11	1	Plastic	Heroin	Cocaine, Heroin
	1	Plastic	Cocaine	Cocaine
	1	Plastic	No Controlled Substances	No Drugs Detected
12	1	Plastic	Cocaine	Cocaine
	1	Glassine	Fentanyl	Cocaine, Fentanyl
13	1	Plastic	Cocaine, Fentanyl, Heroin, 4-ANPP	Cocaine, Fentanyl, Heroin
	1	Glassine	Heroin	Cocaine, Fentanyl, Heroin
14	1	Plastic	Cocaine	Cocaine
15	1	Plastic	Cocaine	Cocaine
16	1	Plastic	Cocaine	Cocaine
17	1	Plastic	Methamphetamine	No Drugs Detected
18	1	Plastic	Methamphetamine	Methamphetamine
19	1	Glassine	Fentanyl, Heroin	Fentanyl, Heroin
	2	Glassine	Fentanyl, Heroin	Fentanyl, Heroin
20	1	Glassine	Fentanyl, Heroin, Tramadol	Fentanyl, Heroin, Tramadol
	2	Glassine	Fentanyl, Heroin, Tramadol	Fentanyl, Heroin, Tramadol
21	1	Glassine	Fentanyl, Heroin, Tramadol	Fentanyl, Heroin, Tramadol
	2	Glassine	Fentanyl, Heroin, Tramadol	Fentanyl, Heroin, Tramadol
22	1	Plastic	MDMA	MDMA
23	1	Glassine	Heroin	Heroin
	2	Glassine	Heroin	Heroin
24	1	Glassine	Fentanyl, Heroin	Fentanyl, Heroin
	2	Glassine	Fentanyl, Heroin	Fentanyl, Heroin
25	1	Glassine	Fentanyl, Heroin, 4-ANPP, Codeine, Ketamine	Fentanyl, Heroin
	2	Glassine	Fentanyl, Heroin, 4-ANPP, Codeine	Fentanyl, Heroin
26	1	Glassine	Heroin	Heroin
	2	Plastic	Heroin	Heroin
27	1	Glassine	Fentanyl, Heroin, 4-ANPP	Fentanyl
	2	Glassine	Fentanyl, Heroin, 4-ANPP	Fentanyl
28	1	Foil	Cocaine	Cocaine
29	1	Plastic	Methamphetamine	Methamphetamine
30	1	Plastic	Cocaine	Cocaine
31	1	Plastic	Cocaine	Cocaine
32	1	Plastic	Cocaine	Cocaine
33	1	Glassine	Fentanyl, 4-ANPP	Fentanyl
	2	Glassine	Fentanyl, 4-ANPP	Fentanyl, 4-ANPP
34	1	Plastic	Methamphetamine	Methamphetamine
35	1	Other	No Controlled Substances	No Drugs Detected
36	1	Plastic	Cocaine	Cocaine
37	1	Plastic	Cocaine	Cocaine
38	1	Plastic	Cocaine	Cocaine
39	1	Paper	Cocaine	Cocaine
40	1	Plastic	Cocaine	Cocaine
41	1	Plastic	Cocaine	Cocaine
42	1	Plastic	Cocaine	Cocaine
	2	Plastic	Cocaine	Cocaine
43	1	Plastic	Cocaine	Cocaine
44	1	Plastic	Cocaine	Cocaine
45	1	Plastic	Eutylone	Eutylone, Cocaine
46	1	Plastic	Fentanyl, Heroin, 4-ANPP	No Drugs Detected
47	1	Plastic	Cocaine	Cocaine

48	1	Plastic	Fentanyl, 4-ANPP	Fentanyl
49	1	Plastic	Cocaine	Cocaine
50	1	Suboxone Packet	Buprenorphine	No Drugs Detected
51	1	Currency	Oxycodone	Oxycodone
52	1	Plastic	Cocaine	Cocaine
53	1	Plastic	Cocaine	Cocaine
54	1	Plastic	Cocaine, Fentanyl, 4-ANPP	Cocaine
	2	Plastic	Cocaine, Fentanyl, 4-ANPP	Cocaine
55	1	Plastic	Buprenorphine	No Drugs Detected
56	1	Plastic	Cocaine, Fentanyl	Cocaine, Fentanyl
57	1	Plastic	Methamphetamine	Cocaine, Methamphetamine
	2	Plastic	Methamphetamine	Cocaine, Methamphetamine
	3	Plastic	MDMA	Cocaine, MDMA
58	1	Plastic	Cocaine	Cocaine
	2	Plastic	Cocaine	Cocaine
	3	Plastic	Cocaine	Cocaine
59	1	Plastic	Fentanyl, Heroin, 4-ANPP, Etizolam, Deschloroetizolam	Cocaine, Fentanyl
	2	Plastic	Fentanyl, Heroin, 4-ANPP, Etizolam	Cocaine, Fentanyl, Etizolam

Table S4. Quantitative LC-MS/MS results for wipes obtained from the inner packaging. Abbreviations for the drugs include C = cocaine, F = fentanyl, H = heroin, D = MDMA, M = methamphetamine, and O = oxycodone. The values presented here have been adjusted from the raw values based on the assumptions explained in the text.

Case #	Item #	Packaging Type	Contents	LC-MS/MS Result (µg)					
				C	F	H	D	M	O
1	1	Plastic	Cocaine	2.46					
2	1	Glassine	Heroin		0.24				
	2	Glassine	Fentanyl, Heroin						
3	1	Plastic	Cocaine	19.53					
4	1	Plastic	Cocaine	0.54					
5	1	Plastic	Cocaine, Heroin, 4-ANPP	0.15					
	1	Plastic	Cocaine	8.16					
6	1	Glassine	Fentanyl, Heroin, 4-ANPP			0.66			
7	1	Plastic	Heroin						
	2	Glassine	Heroin			0.12			
8	1	Foil	Cocaine, Fentanyl, Heroin		1.62	211.00			
9	1	Plastic	Fentanyl, 4-ANPP						
10	1	Plastic	Cocaine	0.87					
11	1	Plastic	Heroin	0.21		3.87			
	2	Plastic	Cocaine	0.12					
	3	Plastic	No Controlled Substances						
12	1	Plastic	Cocaine	4.23					
	2	Glassine	Fentanyl	0.60					
13	1	Plastic	Cocaine, Fentanyl, Heroin, 4-ANPP	0.15	32.90	591.00			
	2	Glassine	Heroin	1.08	2.46	36.30			
14	1	Plastic	Cocaine	3.36					
15	1	Plastic	Cocaine	0.57					
16	1	Plastic	Cocaine	5.34					
17	1	Plastic	Methamphetamine						
18	1	Plastic	Methamphetamine					0.24	
19	1	Glassine	Fentanyl, Heroin			0.24			
	2	Glassine	Fentanyl, Heroin		0.75	10.40			
20	1	Glassine	Fentanyl, Heroin, Tramadol		1.29	9.18			
	2	Glassine	Fentanyl, Heroin, Tramadol		0.63	4.14			
21	1	Glassine	Fentanyl, Heroin, Tramadol		0.57	9.33			
	2	Glassine	Fentanyl, Heroin, Tramadol		0.18	1.92			
22	1	Plastic	MDMA				4.95		
23	1	Glassine	Heroin			6.87			
	2	Glassine	Heroin			1.41			
24	1	Glassine	Fentanyl, Heroin		4.05	172.00			
	2	Glassine	Fentanyl, Heroin		1.20	55.20			
25	1	Glassine	Fentanyl, Heroin, 4-ANPP, Codeine, Ketamine		2.49	1.83			
	2	Glassine	Fentanyl, Heroin, 4-ANPP, Codeine		0.33	0.45			
26	1	Glassine	Heroin			0.75			
	2	Plastic	Heroin			1.08			
27	1	Glassine	Fentanyl, Heroin, 4-ANPP		0.15				
	2	Glassine	Fentanyl, Heroin, 4-ANPP		0.30				
28	1	Foil	Cocaine	1.08					
29	1	Plastic	Methamphetamine					27.39	
30	1	Plastic	Cocaine	0.09					
31	1	Plastic	Cocaine	0.33					
32	1	Plastic	Cocaine	0.30					
33	1	Glassine	Fentanyl, 4-ANPP		2.34				
	2	Glassine	Fentanyl, 4-ANPP		1.23				
34	1	Plastic	Methamphetamine					27.90	
35	1	Other	No Controlled Substances						
36	1	Plastic	Cocaine	2.31					
37	1	Plastic	Cocaine	0.60					
38	1	Plastic	Cocaine	0.18					
39	1	Paper	Cocaine	0.45					
40	1	Plastic	Cocaine	0.60					
41	1	Plastic	Cocaine	2.97					
42	1	Plastic	Cocaine	8.85					
	2	Plastic	Cocaine	1.35					
43	1	Plastic	Cocaine	1.59					
44	1	Plastic	Cocaine	2.37					
45	1	Plastic	Eutylone						

46	1	Plastic	Fentanyl, Heroin, 4-ANPP						
47	1	Plastic	Cocaine	1.08					
48	1	Plastic	Fentanyl, 4-ANPP	0.25	1.08				
49	1	Plastic	Cocaine	1.32					
50	1	Suboxone Packet	Buprenorphine						
51	1	Currency	Oxycodone						19.00
52	1	Plastic	Cocaine	6.39					
53	1	Plastic	Cocaine						
54	1	Plastic	Cocaine, Fentanyl, 4-ANPP						
	2	Plastic	Cocaine, Fentanyl, 4-ANPP	0.03	0.15				
55	1	Plastic	Buprenorphine						
56	1	Plastic	Cocaine, Fentanyl	0.12					
57	1	Plastic	Methamphetamine	0.09					
	2	Plastic	Methamphetamine	0.09				0.30	
	3	Plastic	MDMA	0.40				1.50	
58	1	Plastic	Cocaine	0.24		1.14			
	2	Plastic	Cocaine	1.74	0.03				
	3	Plastic	Cocaine	0.80		0.30			
59	1	Plastic	Fentanyl, Heroin, 4-ANPP, Etizolam, Deschloroetizolam	0.18	0.15	1.62			
	2	Plastic	Heroin, Fentanyl, 4-ANPP, Etizolam	0.09	0.45	5.64			