The Evaluation of Portable Handheld Raman Systems for the Presumptive Identification of Narcotics: Thermo Scientific TruNarc® and Chemring Detection Systems PGR-1064®

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Abstract

Historically, presumptive testing for narcotics has involved colorimetric tests, otherwise known as spot tests. These tests are fast, sensitive, and can categorize a suspected illegal substance to a particular class of drugs. However, the interpretation of the color change is subjective and false positives and negatives are possible. Handheld Raman devices have been developed for forensic application to eliminate the need for colorimetric testing. These user-friendly systems offer a non-destructive means to detect potentially controlled substances, precursors and cutting agents quickly and accurately either within a laboratory system or as a field test by law enforcement.

The goal of this research was to evaluate two handheld Raman systems to determine their ability to accurately analyze narcotic samples. The Thermo Scientific TruNarc® and Chemring Detection Systems PGR-1064® were used to test over a hundred case samples that had previously been tested by colorimetric and GC-MS analysis in the Palm Beach County Sheriff's Office Chemistry Unit. Case samples, which included opiates, stimulants, hallucinogens, and pharmaceutical tablets, were scanned in triplicate on three consecutive days in order to determine reproducibility and repeatability. Results of the Raman scans were compared to the laboratory's validated chemical analysis results. The TruNarc® successfully detected the target drug in 77% of the case samples, and generated reproducible results in 84% of the case samples when the results were compared to the rescans on days two and three. An added benefit to the TruNarc® system is the Type H kit, which utilizes Surface Enhanced Raman Spectroscopy (SERS) to increase Raman scattering and fluorescence quenching, allowing drugs in low concentration or those with high fluorescence to be detected successfully. The PGR-1064® successfully detected the target drug in 36% of the case samples and generated reproducible results in 60% of the case samples when the results were compared to the rescans on days two and three.

These Raman detection systems exhibited the potential to provide accurate and reproducible results for single component samples through the analysis of certified reference standards, however there are intrinsic challenges to the technology of Raman Spectroscopy when dealing with mixtures. Case sample homogeneity was unpredictable where adulterants, diluents and other components were found within the samples. As a result, the

laser may not routinely focus on the target drug within a sample. Additionally, limited sample quantities resulted in inconclusive or unidentified results. The ability to detect forensic narcotic samples likely depends on sample purity, amount, and where on the sample the laser is focused.

The data presented suggests that handheld Raman systems have the potential to detect substances of abuse depending on the specific sample, although further evaluation is necessary for implementation within a laboratory and as a field test. In order to improve Raman-based field testing, additional studies are needed on synthetic drug analogs due to the proliferation of these compounds. Likewise, product development companies should focus on alleviating fluorescence issues of commonly encountered drugs to further enhance the applicability of Raman technology. The opinions, findings, conclusions and recommendations stated in this paper are those of the authors and do not necessarily reflect the vendors or the Palm Beach County Sheriff's Office.

Keywords: *TruNarc®, PGR-1064®, portable Raman spectroscopy, presumptive testing*

Introduction

The currently accepted method to presumptively identify narcotics in the field involve colorimetric wet chemical tests, known as spot tests, to indicate that an illegal substance may be present. This is accomplished by categorizing the unknown substance to a particular class of drugs. Although these colorimetric tests are less specific than confirmatory tests, these tests have been beneficial for many years due to their quickness and sensitivity to major drug classes still encountered in the drug market today[1]. However, there are reported challenges to performing these spot tests[2]; a significant limitation involving any colorimetric test is that interpretation of these tests may be subjective in nature which may lead to false positives and false negatives. In other words, the actual color perceived may vary depending on the color discrimination of the police officer or analyst. While Type II errors of reporting a false negative is undesired and should be avoided in the world of forensics, Type I errors where a false positive is reported is of a more serious consequence. False positive results may result in an individual wrongfully charged and prosecuted for drug crimes or may lead to an extended incarceration time where traumatic experiences may have long-term affects until confirmatory tests are conducted in the laboratory and they are released[2].

Another disadvantage of colorimetric testing involves the safety of police officers where the suspected narcotics may be absorbed through the skin or ingested[3]. For example, in cases containing fentanyl, a drug that has killed thousands in overdoses, police officers must proceed with severe caution since Fentanyl can be easily absorbed through the skin or inhaled if airborne[4]. There are field tests that also contain harmful chemicals. For instance, the Marquis reagent requires careful handling and storage due to the primary ingredient, sulfuric acid, which will burn the skin upon contact[5].

Synthetic drugs are an additional challenge for colorimetric tests as some cannot be classified by the colorimetric tests currently available on the market as these drugs are being continuously produced and modified to evade categorization as a controlled substance under the Controlled Substance Act[6]. Manufacturers struggle to provide reliable, accurate and sensitive spot tests in a timely manner to accommodate the ever

changing chemistry. Consequently, some have suggested that multiple spot tests can be used to categorize the suspected narcotic further; however performing various spot tests is relatively time-consuming and costly for law enforcement agencies and laboratories[6, 7].

Many forensic laboratories and law enforcement agencies are redirecting the focus to the handheld Raman market to eliminate the need for colorimetric testing. This paper will focus on the evaluation of two Raman systems and the feasibility to accurately and reliably detect target drugs within evidentiary case samples that were previously analyzed using confirmatory tests. The vendor's product specifications and features are shown in Table 1[8, 9].

Table 1. The TruNarc® and PGR-1064® specifications[8, 9]

Specifications	TruNarc®	PGR-1064®
Weight	1.25 lbs	2.25 lbs
Size	6.4 x 4.1 x 2.0 in.	2.5 x 7.5 x 6.6 in.
Laser and power output	785 nm; 250 mW	1064 nm; 500 mW
Library	Controlled substances, precursors, and cutting agents, including synthetic cathinone's, and cannabinoids	Controlled substances including synthetics, precursors, cutting agents, explosives, explosive precursors and warfare agents
Data Export	Admin Software; connected via USB	Excel; connected via USB
Analysis time	90 seconds or less	10 seconds or less
Self-Diagnostic Test	Polystyrene lid attached to device	Polystyrene card
Features	Type H kit; locked library; spectral analysis by staff chemists (Reachback support); printable spectra	Adjust the power output as necessary; correlation match; customizable library; printable spectra
Cost	~$22,000	~$34,000

These Raman systems have the capability of providing many benefits over the existing presumptive technique by decreasing the rate of false positives and increasing the safety and well-being of the officers in the field. Moreover, Raman systems also have the potential to reduce backlog for laboratory analysts in high drug possession areas. Recently, Jacksonville State University Center for Applied Forensics evaluated the TruNarc® in order to decrease the backlog of drug cases. The protocol used by the Jacksonville police included testing using Raman technology and if the results were positive for an illegal drug, the Raman results were

disseminated to the District Attorney to be used before the grand jury. Defendants accused of simple possession charges were typically offered a plea agreement based on the results of the Raman report. If the defendant accepted the plea agreement, the evidence was not further analyzed by the lab, thereby decreasing the backlog burden[10].

These systems operate by using Raman spectroscopy, a vibrational spectroscopy technique that provides a molecular fingerprint for the compound of interest. This method relies on Raman scattering or the inelastic scattering of photons, from a laser source, after it comes in direct contact with the molecules of interest. This Raman scattering occurs when there is a change in a molecule's polarizability during a molecular vibration. Once the light is scattered, it's captured and separated before the detector measures the intensity of the light at each wavelength and converts it to a spectrum. Once the spectrum is produced, it is compared against the company's in-house spectral library using a search algorithm to identify the substance[11]. A schematic representation of this technique is depicted in Figure 1[12].

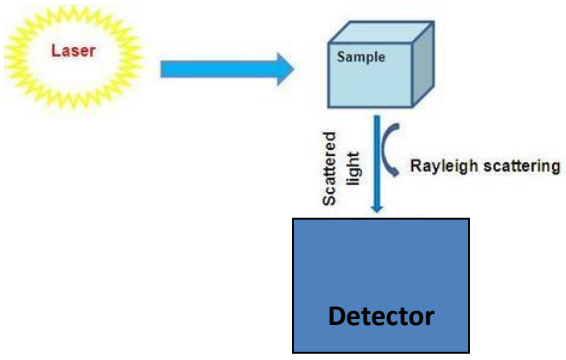

Figure 1. A schematic representation of Raman Spectroscopy[12].

According to the Scientific Working Group for the Analysis of Seized Drugs (SWGDRUG), Raman spectroscopy is listed as a category A technique, which means it has one of the highest discriminating powers for the analysis of controlled substances[13]. One of the major advantages in using Raman Spectroscopy is its nondestructive in that the analysis does not damage or destroy the substance. Also, Raman requires little to no

sample preparation and can analyze samples in water or through glass and polymer packaging, which can help minimize contamination, reduce exposure, and preserve evidence while in the officer's custody[10].

Despite such advantages, an important challenge when using Raman spectroscopy is the interference of fluorescence, which can typically mask the Raman signal completely and result in a significant amount of background noise. Fluorescence is encountered with many substances, particularly plant-based narcotics, and substances that are pigmented with an array of colors. For this reason, substances like heroin and illicit tablets that contain pigments and binders are challenging, and results from plant material like marijuana are impossible to generate. Also, sample burning can occur on darkly colored substances like black tar heroin if the laser power excitation is significant[14, 15]. Moreover, fluorescence is intensified when these Raman systems are operating at a lower excitation wavelength. For example, although most substances can provide a Raman signal at 785 nm, producing a clear spectrum for highly fluorescent materials is almost impossible. In one study performed by Yang and Akkus, background fluorescence was reported to be 500 times weaker when using a 1064 nm laser than that obtained when using a 785 nm laser[16]. For this reason, more product development companies are now designing systems at higher excitation wavelengths, which is one of the main differences noted between the TruNarc® (785 nm laser) and PGR-1064®(1064 nm laser). However once the excitation wavelength is increased, the strength of the Raman signal varies inversely with the fourth power of the excitation wavelength. In other words, more Raman scattering will occur with the more energetic excitation wavelength. For example, if a sample is analyzed with a 785 nm source and a 1064 nm source, more Raman scattering will occur when analyzed with the 785 nm excitation source[17]. Another disadvantage to Raman spectroscopy is that the Raman signal is typically weak for most substances as most of the light is elastically scattered or Rayleigh scattered. For this reason, Raman systems have notch filters built into the system to remove the Rayleigh scattered light; however it is still well known that not all substances will scatter with the same efficiency[18].

Because of the challenges shown with fluorescence for some chemicals, Thermo Scientific opted to develop the Type H kit, an added advantage that could be used with the TruNarc® when the traditional point and shoot

method is deemed unsuitable. Not only can this kit be used with highly fluorescent materials, but also with drugs in low concentrations that are unable to be detected by using the conventional Raman spectroscopy[19]. The Type H kit utilizes Surface Enhanced Raman Spectroscopy (SERS) which is a surface-sensitive technique that enhances the Raman signal by absorbing the molecules onto a roughened metal surface. When the laser hits the silver or gold metal surface, plasmons or oscillations of electron density will occur which will interact with the molecules of interest thereby increasing Raman scattering and decreasing the fluorescence[11].

The Palm Beach County Sheriff's Office Chemistry Unit investigated the TruNarc® and PGR-1064® Raman systems to evaluate each system's ability to accurately and reliably detect single and multi-component samples. This goal was accomplished with certified reference standards and forensic evidentiary samples.

Materials and Methods

Reagents and Chemicals

Table 2 lists the fifteen certified reference standards that were used for this study. Quinine (Lot # 735364) and Sodium Bicarbonate Powder (Lot # J26601) were purchased from J.T. Baker (Phillipsburg, NJ). The internal standard, aminopyrine (4-dimethylaminoantipyrine) was prepared and used for the blanks throughout GC-MS analysis.

Table 2. The reference standards analyzed using the handheld Raman systems.

Standards	Company
Alprazolam	Upjohn
Fentanyl Citrate	United States Pharmacopeia
Methadone HCl	Sigma-Aldrich
Clonazepam	Merck
Cocaine HCl	Sigma-Aldrich
Cocaine Base	Sigma-Aldrich
Ethylone HCl	Cayman Chemical
Methylone HCl	Sigma-Aldrich

Heroin	Cayman Chemical
Hydrocodone Bitartrate	Endo
Hydromorphone Dipotassium	Sigma-Aldrich
Oxycodone HCl	Endo
Methamphetamine HCl	Sigma-Aldrich
MDMA HCl	Cayman Chemical
α-PVP HCl	Cayman Chemical

Instrumentation

The TruNarc® system was obtained from Thermo Scientific (Waltham, MA S/N: TN1078). The PGR-1064® system was obtained from Chemring Detection Systems (Charlotte, NC S/N: 0025). An Agilent Technologies 6890N Gas Chromatograph with a 5973 Mass Selective Detector from Hewlett Packard (Miami, FL) was used for confirmatory analysis throughout this project. The GC-MS instrument parameters described in Table 3 were used for the identification of case samples.

Table 3. GC-MS instrument parameters.

GC parameters	Column type	DB-5 Restek Rxi-5ms
	Column dimensions	15.0m x 250µm x 0.25µm nominal
	Column mode	Constant flow
	Injection volume	1.0 µL
	Split ratio	75:01
	Initial Temp	200 ºC
	Ramp Temp 1	30 ºC/min
	Ramp Temp 2	45 ºC/min
	Final Temp	280 ºC
MS parameters	Solvent delay	0.50 min
	Acquisition mode	Scan

Self-Diagnostic Test

Self-checks were performed on both systems to ensure the devices were functioning properly for analysis. Note self-checks can be done as often as the user wishes. Self-checks performed on the TruNarc® were accomplished by using the polystyrene lid attached to the instrument's nose cone. This self-check was performed between every new standard and case sample. The PGR-1064® self-check was performed by using a polystyrene card placed up against the laser of the system. This self-check was performed three times; once at the beginning of the analysis, halfway through, and once at the end of the analysis. If a pass result was obtained, then the systems would be used to scan the reference standards and case samples.

Drug Standards Sample Preparation and Analysis

Because each reference standard was stored in darkly colored vials, it was necessary to transfer some of each standard to a clear vial for the Raman instrument to effectively analyze the sample. Approximately 10 mg of each standard was placed in a clear GC vial. If there was not an adequate amount of standard to cover the bottom of the vial, a GC vial insert was used and placed into the GC vial. Each vial was labeled appropriately with the standard name and reference number.

Once it was confirmed that the systems were working correctly, each of the GC vials was scanned in triplicate using the TruNarc® and PGR-1064® Raman systems. Then, the scan results were documented and exported onto a computer using either TruNarc's® software or Excel respectively. The results of the scans were compared to the known standards.

Casework Evidence Samples Preparation and Analysis

Adjudicated and non-adjudicated case samples were analyzed in this study. For the non-adjudicated casework samples, the scans were performed in the presence of the qualified forensic chemist through packaging and before sampling when possible. The Palm Beach County Sheriff's Office Chemistry Unit's current laboratory protocol was used to evaluate each adjudicated case sample that was marked for destruction. Each case sample was documented appropriately before sampling. This documentation included the date, case number,

description of the evidence, and weight. The weight included a tare and net weight. The Marquis and Cobalt Thiocyanate colorimetric tests were then performed on cases involving powdered samples and illicit tablets while if pharmaceutical tablets were involved, they were presumptively identified using the Internet source drugs.com.

Case samples were placed into clear plastic bags if not already done so and scanned using the TruNarc® and PGR-1064® systems. If the result was a cutting agent, it was assumed that the laser was interacting more frequently with the cutting agent rather than the drug of interest. To account for this, the sample was shaken in-between each scan and scanned in a different area to ensure homogeneity. If tablets were involved, one tablet's coating was scraped off and cut in half before placed into a plastic bag and scanned. Lastly, the scan results were exported onto the computer.

GC-MS confirmed the identification of each case sample. In a GC vial, a small amount of sample was dissolved in 1 mL of an internal standard. An internal standard blank was run between every sample to detect carryover. Confirmation was performed by comparison of the retention time and mass spectra of the unknown to a concurrently analyzed control prepared from certified reference material. Finally, the results of the Raman scans were compared to the laboratory results.

TruNarc®: Type H kit

The vendor, Thermo Scientific, provided a Type H kit to be used in conjunction with the TruNarc® when the point and shoot method was not efficacious for the detection of drugs in low concentration or those with high fluorescence. This Type H kit is included with the TruNarc device and is comprised of two elements: A test stick and a test vial of ethanol. The Type H kit procedure was performed by placing a small amount of sample onto the stick and inserting the stick into a solution of ethanol. After about ten seconds, the stick was removed and allowed to dry for two minutes at room temperature before the stick was scanned. Each stick was scanned with the TruNarc in triplicate. This procedure was applied to the casework evidence samples when deemed necessary.

Accuracy

Accuracy measures the closeness of agreement between the test results and the true values. For this part of the study, the reference standards, and all case samples were used by comparing the results from the scans to either the known standards or the laboratory's results.

Reproducibility

Reproducibility measures the variation, or inconsistency, of each device by having a single analyst perform a scan a number of times to determine if similar scan results are obtained each time. Reproducibility was evaluated by scanning each reference standard and adjudicated case samples in triplicate on day one, and then comparing these results to the rescans on days two, and three.

Sensitivity

Sensitivity measures how often a system will correctly identify the drug of interest when there is a small amount of target drug present in a sample. The sensitivity study was conducted by weighing out selected concentrations of a target drug at decreasing ratios mixed with a cutting agent at increasing ratios, while pharmaceutical tablets were analyzed as they were at various dosages. Certified reference standards of cocaine base and heroin were prepared with sodium bicarbonate and quinine respectively, and scanned in triplicate by each system. Due to the limited quantities available, these mixtures contained roughly 10-20 mg of cocaine and heroin. Table 4 lists the mixtures prepared at selected concentrations.

Table 4. Concentrations of cocaine and heroin mixed with sodium bicarbonate and quinine respectively.

Drug	**Cutting Agent**	**Ratios**
Cocaine Base	Sodium Bicarbonate	2:8 1:9 1:10 1:20
Heroin	Quinine Hydrochloride	2:8 1:9 1:10

Selectivity

Selectivity measures the degree to which a system can identify the target drug accurately in the presence of other components. These other components present in the sample can have a considerable effect on the ability to detect the target drug. These interferences can be attributed to adulterants, diluents, and precursor chemicals commonly mixed with drugs sold on the street. This study was carried out by identifying if each system predominately identified the target drug rather than the other interferences. If other components were identified, the bag was shaken, and the area of the sample being scanned was varied to increase the likelihood of detecting the target drug.

Results and Discussion

Reference standards

The accuracy and reproducibility data gleaned from the scan results include the reference standards and casework evidence samples which can be found in Appendix A and B, respectively. The scan results for the evidence samples in Appendix B are listed in chronological order of when they were tested. The samples were comprised of non-adjudicated case samples that were currently being analyzed by the Palm Beach County Sheriff's Office Chemistry Unit and cases previously marked for destruction. For this reason, accuracy and reproducibility were illustrated in separate tables (Tables 11, 12, 13, 14) for the two types of case samples in Appendix B. When determining the reliability of each system, only the cases marked for destruction were rescanned on days two and three, however when determining the accuracy of each system, both the adjudicated and non-adjudicated case samples were used. An 80% or higher met the requirements for a system to be considered accurate and reproducible.

The statistics are shown as percentages throughout this paper. Percentages were calculated by adding the number of times the scan result occurred divided by the total number of scans. These percentages were determined with Tables 8 and 9 in Appendix A. The accuracy rate for each system was determined by whether or not the system correctly identified the drug of interest in the sample. The reproducibility of each system was determined by comparing the scan results on day one to the rescans on days two and three including both

correct and incorrect results. For example, three inconclusive results or three incorrect results over the three day period were still considered consistent, but varying results across this time period were not considered consistent.

Reference standards were scanned in triplicate by the TruNarc® and PGR-1064® to determine if handheld Raman systems can accurately and reliably screen single component samples. The results showed that the TruNarc® and PGR-1064® can produce accurate and reliable results for reference standards. Table 5 demonstrates the accuracy results of the certified reference standards obtained from each system. A higher accuracy percentage was expected for the reference standards where purity was not of concern since these standards were obtained from certified reference sources and no other components would be identified as these standards are single component samples. Consistent results were produced by the TruNarc® (86.6%) and PGR-1064® (93.3%), illustrating that these systems are relatively reliable for single component samples.

Table 5. Accuracy of certified reference materials per the TruNarc® and PGR-1064® Raman systems.

	TruNarc® S/N: TN1078	**PGR 1064® S/N: 0025**
Accuracy	97.6%	98.5%
Misidentification	0%	1.5%
Inconclusive/Unidentified	8.15%	0%
Other Components Identified	0%	0%

Out of the fifteen standards, the TruNarc® system results were inconsistent in the detection of alprazolam and hydrocodone. These scans were submitted to the vendor's reachback support where staff chemists performed a spectral analysis on these findings. It was determined that because alprazolam is commercially found in low concentrations, its spectrum is only in the library as an H kit chemical meaning that the TruNarc® will not obtain accurate results using conventional Raman spectroscopy without assistance from the Type H kit. For this reason, the nine initial scans using the point and shoot method were not used in the accuracy calculation for any analysis involving alprazolam however the initial scans were still included in the calculated inconclusive percentage. With the aid of the Type H kit, an inconclusive result for the alprazolam standard was obtained on day one, but was successfully detected on days two and three. These inconclusive results could be due to the

laser not being focused on an area of the stick where the drug may be present or not allowing enough time for the stick to dry. For hydrocodone, a spectrum does not exist in the vendor library making the TruNarc® unsuitable for the analysis of hydrocodone; therefore, these analyses were not included in the percentage calculations of the TruNarc®. The PGR-1064® system demonstrated difficulty with the hydromorphone standard by misidentifying it as heroin on day two. This misidentification could be attributed to the system identifying a peak of hydromorphone that was relatively similar to a peak of heroin although this was not verified.

Casework evidence samples

The validated presumptive drug detection method currently used for evidentiary case samples in the Palm Beach County Sheriff's Office Chemistry Unit includes colorimetric testing and pharmaceutical identification through approved reference sources (Internet source drugs.com), and GC-MS is used to confirm the identity of the samples. Once the conventional results were obtained for the case samples, each sample was scanned in triplicate using the Raman systems, and the results were compared to the results of the current testing protocol. Table 6 summarizes the accuracy results for the case samples obtained from each system.

Table 6. Accuracy of case samples per the TruNarc® and PGR-1064® Raman systems.

	TruNarc® S/N: TN1078	**PGR 1064® S/N: 0025**
Accuracy	76.9%	36.1%
Misidentifications	0.60%	1.46%
Inconclusive/Unidentified	13.3%	21.8%
Other Components Identified	9.18%	40.6%

The PGR-1064® was 40.8% less accurate than the TruNarc®, which may be in part due to the Type H kit component used in the detection process for roughly 28% of the destruction case samples. Note that since the Type H kit requires sample consumption, it was not used in the analysis of the non-adjudicated case samples as only validated methods and technologies may be used on active case evidence. Thus, uncertainty about what active case samples may have required the Type H kit for identification remains unknown. While the Type H kit further enhances the results of the TruNarc®, drawbacks include loss of the simplicity of the device and

requirement that officers and laboratory personnel to come into direct contact with the sample. Use of the Type H kit not only raises an issue with safety, but also the preservation and contamination of evidence. Likewise, the process of training the officers in what is considered a scientific laboratory skill in order to use and interpret Type H kit derived data needs to be a serious consideration.

A significant concern was whether these Raman systems would produce false positives or false negatives. During this study, no non-illegal substances tested positive for the presence of drugs; however both systems had several misidentifications. The PGR-1064® generated eleven misidentifications, while the TruNarc® generated five misidentifications. These results are shown in Appendix B in Table 12. For example in several occasions both tramadol and methadone were misidentified by the PGR-1064® as temazepam and diazepam tablets. In another instance, the TruNarc® misidentified methadone as fentanyl. Although the percentages of misidentifications is low (0.5-2%), misidentifications can have a significant impact on the criminal charges and an individual's freedom and personal life.

The PGR-1064® generated false negatives as well, and although the calculated percentage is higher than the TruNarc, the detection of these other components can be reasoned through several observations. 1) Street samples vary in purity, where most are mixed with adulterants and diluents to either bulk the sample or mimic the effects of the drug in order to increase the profit for the dealers. As a result the amount of drug will be in low concentration in relation to these other components making the detection of the target drug difficult. 2) If the laser is focused on one area of the sample, it may be focused on a particle from another component rather than the target drug. Therefore, several scans may be necessary in order to detect the target drug. These observations were further addressed during the sensitivity study by preparing a cocaine base and heroin standard at decreasing ratios with increasing ratios of cutting agents. The scan results for the mixtures prepared at various concentrations are shown in Table 7. The results illustrate that these systems are concentration dependent; as the amount of cutting agent increases, the detection of the target drug decreases accordingly. Similar results are observed with low-dose pharmaceutical tablets, where the non-active ingredients that comprise the majority of the tablet were predominately identified rather than the drug of interest. These results

for the pharmaceutical tablets can be found in Appendix B in Table 13. The TruNarc® instrument was unable to detect heroin or quinine hydrochloride in the 1:10 and 1:20 ratios since both components are found in the company's library. For this reason, Thermo Scientific Reachback Support staff was contacted. The explanation provided was that the quinine spectrum in the TruNarc library does not include quinine in the hydrochloride form. Because the device was not able to adequately explain the spectra data it led to inconclusive results.

Table 7. Scan results of the mixture study involving cocaine and heroin standards with each respective cutting agent.

		TruNarc® S/N: TN1078			**PGR 1064® S/N: 0025**		
Sample	**Ratios**	**Trial 1 Scan Result**	**Trial 2 Scan Result**	**Trial 3 Scan Result**	**Trial 1 Scan Result**	**Trial 2 Scan Result**	**Trial 3 Scan Result**
Cocaine: Sodium Bicarbonate (Baking Soda)	2:8	Cocaine Base	Cocaine Base	Cocaine Base	Cocaine Freebase	Cocaine Freebase	Cocaine Freebase
	1:9	Cocaine Base	Cocaine Base	Cocaine Base	Cocaine Freebase	Cocaine Freebase	Cocaine Freebase
	1:10	Cocaine Base	Baking Soda	Baking Soda	Cocaine Freebase	Sodium Bicarbonate	Cocaine Freebase
	1:20	Baking Soda	Baking Soda	Baking Soda	Sodium Bicarbonate	Sodium Bicarbonate	Sodium Bicarbonate
Heroin :Quinine*	2:8	Heroin	Heroin	Inconclusive	Heroin	Quinine hydrochloride	Heroin
	1:9	Inconclusive	Inconclusive	Inconclusive	Quinine Hydrochloride	Quinine hydrochloride	Quinine hydrochloride
	1:10	Inconclusive	Inconclusive	Inconclusive	Quinine Hydrochloride	Quinine hydrochloride	Quinine hydrochloride

*A ratio of 1:20 was not included since the results indicated it could not detect heroin in previous instances.

4) The scanned data also indicated that some non-target drug components within the sample can invoke strong Raman scattering such that the Raman signal will cause significant interference often masking the Raman signal from the target drug. For example, in a study performed by Thermo Scientific, the TruNarc® required 40% of cocaine when mixed with benzocaine, a drug that displays strong Raman scattering, in order to make a reliable identification[20].

Inconclusive and unidentified results were obtained for case sample's involving heroin, ecstasy tablets, and pharmaceutical tablets. These results were likely attributed to the Raman signal being masked by the interference from fluorescence. Additionally, several of these cases only had a limited amount of sample present, making identification difficult as the Raman systems are unable to provide a successful identification on trace quantities of samples. Also, not all target drugs will be in a company's library, which can lead to an inclusive or unidentified result for these detection systems.

Out of the 68 adjudicated evidence samples scanned by the TruNarc®, 83.8% of these samples provided consistent results. However, the likelihood of producing the same results can be affected when scanning a certain area of the sample, especially when analyzing multi-component samples. Out of 68 case samples scanned by the PGR-1064®, 60.3% of these cases provided consistent interpretable results. Most of the variation with each Raman system was attributed to the laser being focused on various non-active ingredients, lactose and cellulose, which are present in pharmaceutical and illicit tablets.

Cocaine case samples

Forty-six cocaine samples were scanned during this study and the results of the scans can be found in Tables 13 and 14 (Appendix B). Out of a total of 198 scans, The TruNarc® correctly screened cocaine in 98.8% of the casework samples while the PGR-1064® successfully detected cocaine in 97.2% of the casework samples. However, several false negative's occurred with both Raman systems. In some instances, a non-illegal substance, benzocaine, was identified which is commonly found as a cutting agent mixed with cocaine in street samples. Of the forty-six samples, nineteen were analyzed using a colorimetric test Cobalt Thiocyanate, a pink solution that forms a blue precipitate in the presence of cocaine. Of these samples, all produced the correct color change resulting in an accuracy rate of 100%. These results indicate that both chemical color tests and Raman techniques can provide accurate results for cocaine; however, further validation studies should be conducted to determine if additional scans may be required to detect the target drug.

Heroin case samples

Seven heroin samples were scanned during this study and the results of the scans are illustrated in Table 13 (Appendix B). Out of a total of 81 scans, the TruNarc® detected heroin in 44.4% of these case samples including combined results from the point and shoot method and the Type H kit. While the TruNarc's point and shoot method was not effective for these samples, all heroin samples were successfully detected with the aid of the Type H kit. Non-adjudicated heroin samples did not undergo analysis per the Type H kit, which affected the overall accuracy results and led to inconclusive results in 55.6% of samples. These inconclusive results are

likely due to the increased fluorescence commonly encountered with heroin. Out of a total of 45 scans, the PGR-1064® detected heroin in 24.4% of the casework samples, and produced an unidentified result in 42.2% of the casework samples. However, the PGR-1064® detected several other non-illegal components in 33.3% of the casework samples. These other components were caffeine, quinine, mannitol and lactose, which are commonly found with heroin to bulk the sample. In most cases involving heroin, unidentified results occurred partly due to the low concentrations of heroin or limited amount of sample present rather than fluorescence. For example, in the cases involving core samples of heroin taken from the reverse narcotic stockpile, the PGR-1064® successfully detected heroin in every scan, while the TruNarc® did not detect heroin in any scan. These results suggest that using a higher excitation wavelength can in fact alleviate some interference of fluorescence although further evaluation studies should be conducted to confirm this observation. Of the seven samples, four were color tested with Marquis, a clear solution that forms a purple color in the presence of heroin. Of these samples, all produced the correct color change resulting in an accuracy rate of 100%. As can be seen from the results, the detection of heroin is a significant challenge because of the fluorescence and generally low concentrations that can be found within a sample. The SERS testing performed for heroin appears to be necessary for the detection of heroin, and can be considered more effective than the point and shoot method of these Raman systems. Since there was a limited sample size, more samples are necessary in order to form a sound conclusion on the applicability of these portable handheld Raman systems to accurately and reliably detect heroin in case samples.

Ecstasy tablets

One significant challenge involving ecstasy tablets is that the concentration of MDMA varies in the presence of other components. Generally, ecstasy tablets not only contain MDMA, but other stimulants like amphetamine, methamphetamine, and caffeine. For this reason, the percentages calculated from Table 11 include the MDMA and methamphetamine tablets for a total of nine tablets. Out of 111 scans, the TruNarc® detected MDMA in 53.2% of the casework samples and detected methamphetamine in 5.41% of these cases. Additionally, the TruNarc® detected caffeine, a popular adulterant, in 32.4% of the casework samples. However, in several

instances, the Type H kit was required in order to successfully detect MDMA. Out of 75 scans, the PGR-1064® system was unable to detect MDMA successfully in all but one occasion. Instead caffeine and lactose were detected in 61.3% of the casework samples, and an unidentified result was obtained in 37.3% of the casework samples. Because most of these tablets involved two target drug components, an accuracy rate was not reported for color testing.

Another significant challenge involving these tablets is that they often contain numerous synthetic compounds within the supposed ecstasy tablets. For this reason, seven tablets assuming to be MDMA were analyzed by the TruNarc® and PGR-1064® systems. These tablets were found mixed with several components including TFMPP, BZP, MDPV, 5-MeO-DiPT, and BTCP among others. Out of 39 total scans, the TruNarc® detected one or more components successfully in 79.5% of these samples, while the PGR-1064® correctly detected 10.3% of these samples. Of these components, it was determined that BTCP's spectrum is not found in either company's library; therefore BTCP would not be identified. Since many of these drugs do not give a positive color test by cobalt thiocyanate or Marquis, an accuracy rate was not reported for this color testing.

Pharmaceutical tablets

Thirty-three pharmaceutical tablets were analyzed during this study and the results of the scans are displayed in Table 13 (Appendix B). These tablets included alprazolam, hydromorphone, clonazepam, tramadol, methadone and oxycodone. Some of the low-dose tablets of alprazolam and hydromorphone required the Type H kit in order to be detected successfully. Out of 297 scans, the TruNarc® was able to detect the target drug in 80.1% of the casework samples. However, the PGR-1064® was successful in less than 1% of these cases. PGR-1064's focus was primarily on inactive ingredients, lactose and cellulose, which are binders used to form the tablets (75.8%). Although lactose and cellulose were predominately identified instead of the drug of interest, a "possible mixture" result containing the target drug was found in nine cases involving higher dosage tablets of oxycodone and tramadol. However, because of the low correlation match for the target drug, the identification was deemed incorrect. Although pharmaceutical identification is possible with portable handheld Raman

systems, such testing may be considered unnecessary since these tablets are generally not color tested, and are presumptively identified based on the officers experience and approved reference sources.

Emerging Synthetic Drug analogs

Due to their similar molecular structures and seemingly constant modifications, there was uncertainty on whether portable Raman spectroscopy can aid in the identification of emerging synthetic drug analogs (cathinones, phenethylamines and cannabinoids). Five α-PVP samples were analyzed by each system. Out of a total of 15 scans, the results showed that the TruNarc® was able to detect α-PVP in 40.0% of the samples while the PGR1064® detected α-PVP successfully in 26.7% of these samples. In addition, the PGR-1064® misidentified α-PVP as structurally similar cathinones, MDPV and diethylcathinone. As can be seen from these results, the specificity for identifying these analogs may be limited, however the ability to indicate the drug class by base structure can still be considered useful in the field for indication that an illicit drug may be present. However, more evaluations are necessary in order to form a sound conclusion regarding the instruments effectiveness on these analogs. Although these portable devices are not currently able to test on cannabis materials, pure powder forms of synthetic cannabinoids like JWH-018, UR-144, AM -694 and AB-FUBINACA among others are found in both companies library, suggesting it is possible for cannabinoids to be detected successfully. However, since no synthetic cannabinoids were analyzed in this study, its capability in this detection remains unknown.

Future studies and system improvements

An important advancement in improving portable Raman spectroscopy is to weaken the fluorescence interference in typically encountered drugs. Surface enhanced Raman spectroscopy (SERS) alleviated fluorescence; however SERS does require additional steps in order to perform the analysis which could inhibit effective use in the field.

Also, users should have the option to include a case number or any other valuable information related to the sample before analysis takes place, allowing the user to keep track of the results in a more efficient manner.

In regards to the TruNarc®, this system can be enhanced by including a correlation score with library matches, and providing the ability to view the spectra on the device in order to be an accepted practice in a laboratory setting. Furthermore, expanding the number of scans allowed to be saved on the device would also be beneficial. In regards to the PGR-1064®, having a polystyrene apparatus attached to the device would be beneficial to officers in the field rather than keeping track of the card. Also, viewing software should be developed in order to export the results on the computer more efficiently.

Furthermore, reproducibility studies should be carried out to determine if similar results are achieved in other laboratories since a wide diversity of drugs can be encountered throughout geographical areas. Such studies will aid in the determination if portable Raman spectroscopy is applicable to an agency's needs where some drugs are more prevalent than others.

Conclusion

Two handheld Raman systems were evaluated to determine the potential applicability to detect illegal substances accurately and reliably either within a laboratory system or as a field test by law enforcement. The Thermo Scientific TruNarc® and Chemring Detection Systems PGR-1064® were used to test over a hundred case samples by colorimetric and GC-MS analysis in the Palm Beach County Sheriff's Office Chemistry Unit. Each case sample, which included opiates, stimulants, hallucinogens, and pharmaceutical tablets, was scanned in triplicate on three separate days in order to determine reproducibility. To evaluate each system, the results of the Raman scans were compared to the laboratory results. The TruNarc® detected the target drug in 77% of the casework samples, and produced consistent results in 84% of the case samples when the results were compared to the rescans on days two and three. The detection applicability is partially due to the Type H kit that utilizes Surface Enhanced Raman Spectroscopy (SERS), a technique that enhances Raman scattering and fluorescence quenching to successfully detect target drugs in low concentration or those highly fluorescent. The PGR-1064®

detected the target drug in 36% of the case samples and produced consistent results in 60% of the case samples when the results were compared to the rescans on days two and three.

There are several inherent limitations to Raman Spectroscopy that are not due to manufacturer design. For example, a significant limitation is background interference which can include noise from fluorescence, or mixture interferences from other sample components that can mask the Raman signal of the target drug. The use of Raman spectroscopy to analyze darkly pigmented samples is limited and can result in sample burning. Furthermore, the ability of these systems to detect illegal substances depends on sample purity, amount, and where on the sample the laser is focused. The first observation was that most of the case samples varied in purity due to the other components found within the sample. Secondly, if limited amount of sample was present, the laser may not detect the drug and the system would generate an inconclusive or unidentified result. The third observation was that because the laser is focused on one area of the sample, the likelihood of reproducible results can be affected when scanning a certain area of the sample that may be focused on a particle from the cutting agent rather than the drug of interest.

These results suggest that handheld Raman systems have the potential to detect illegal substances, however, due to the nature of forensic evidentiary narcotic samples and pharmaceutical preparations there are advantages and drawbacks to the use of Raman as a presumptive screening tool. The results indicate these Raman systems are useful in the detection for commonly encountered substances especially in the purified form; however, reliability will depend on the composition, quality and quantity of a specific sample. Further evaluation is necessary to determine the implementation for these detection systems within a laboratory and as a field test.

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Appendix A

Table 8. TruNarc® accuracy results for each reference standard scanned in triplicate on days one, two, and three.

Reference Standards	Number of scans	Number of TruNarc Positive Identifications	Misidentification of drug	Number of Inconclusive Results	Other Components Identified	Was the H kit used?	Comments
Alprazolam*	18	7	0	11	0	Yes	
Cocaine Base	9	9	0	0	0	No	
Cocaine HCl	9	9	0	0	0	No	
Clonazepam	9	9	0	0	0	No	
Ethylone HCl	9	9	0	0	0	No	
Fentanyl Citrate	9	9	0	0	0	No	
Heroin	9	9	0	0	0	No	
Hydrocodone Bitartrate**	9	0	0	9	0	Yes	Hydrocodone not in library
Hydromorphone Dipotassium	9	9	0	0	0	No	
Methadone HCl	9	9	0	0	0	No	
Methamphetamine HCl	9	9	0	0	0	No	
Methylone HCl	9	9	0	0	0	No	
MDMA HCl	9	9	0	0	0	No	
Oxycodone HCl	9	9	0	0	0	No	
α-PVP HCl	9	9	0	0	0	No	
TOTAL	**144**	**124**	**0**	**20**	**0**		

*Initial scans were not included in accuracy calculation. ** Hydrocodone was not included in any calculation since it's not in company's library.

Table 9. PGR-1064® accuracy results for each reference standard scanned in triplicate on days one, two, and three.

Reference Standards	Number of scans	Number of PGR-1064 Positive Identifications	Misidentification of drug	Number of Unidentified Results	Other Components Identified	Comments
Alprazolam	9	9	0	0	0	
Cocaine Base	9	9	0	0	0	
Cocaine HCl	9	9	0	0	0	
Clonazepam	9	9	0	0	0	
Ethylone HCl	9	9	0	0	0	
Fentanyl Citrate	9	9	0	0	0	
Heroin	9	9	0	0	0	
Hydrocodone Bitartrate	9	9	0	0	0	
Hydromorphone Dipotassium	9	7	2	0	0	Heroin-2
Methadone HCl	9	9	0	0	0	
Methamphetamine HCl	9	9	0	0	0	
Methylone HCl	9	9	0	0	0	
MDMA HCl	9	9	0	0	0	
Oxycodone HCl	9	9	0	0	0	
α-PVP HCl	9	9	0	0	0	
TOTAL	**135**	**133**	**2**	**0**	**0**	

Table 10. A comparison of the scan results for each reference standard scanned by the TruNarc® and PGR-1064® Raman systems.

		TruNarc S/N: TN1078			PGR 1064 S/N: 0025		
Reference Standards	**Days of Scans**	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 1**	**Trial 2**	**Trial 3**
Alprazolam	**Day 1**	Inconclusive H kit: Inconclusive	Inconclusive H kit: Inconclusive	Inconclusive H kit: Inconclusive	Alprazolam	Alprazolam	Alprazolam
	Day 2	Inconclusive H kit: Alprazolam	Inconclusive H kit: Alprazolam	Alprazolam H kit: Alprazolam	Alprazolam	Alprazolam	Alprazolam
	Day 3	Inconclusive H kit: Alprazolam	Inconclusive H kit: Alprazolam	Inconclusive H kit: Alprazolam	Alprazolam	Alprazolam	Alprazolam
Cocaine Base	**Day 1**	Cocaine Base	Cocaine Base	Cocaine Base	Cocaine Freebase	Cocaine Freebase	Cocaine Freebase
	Day 2	Cocaine Base	Cocaine Base	Cocaine Base	Cocaine Freebase	Cocaine Freebase	Cocaine Freebase
	Day 3	Cocaine Base	Cocaine Base	Cocaine Base	Cocaine Freebase	Cocaine Freebase	Cocaine Freebase
Cocaine HCl	**Day 1**	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl
	Day 2	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl
	Day 3	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl
Clonazepam	**Day 1**	Clonazepam	Clonazepam	Clonazepam	Clonazepam	Clonazepam	Clonazepam
	Day 2	Clonazepam	Clonazepam	Clonazepam	Clonazepam	Clonazepam	Clonazepam
	Day 3	Clonazepam	Clonazepam	Clonazepam	Clonazepam	Clonazepam	Clonazepam
Ethylone HCl	**Day 1**	Ethylone	Ethylone	Ethylone	Ethylone	Ethylone	Ethylone
	Day 2	Ethylone	Ethylone	Ethylone	Ethylone	Ethylone	Ethylone
	Day 3	Ethylone	Ethylone	Ethylone	Ethylone	Ethylone	Ethylone
Fentanyl Citrate	**Day 1**	Fentanyl	Fentanyl	Fentanyl	Fentanyl	Fentanyl	Fentanyl
	Day 2	Fentanyl	Fentanyl	Fentanyl	Fentanyl	Fentanyl	Fentanyl
	Day 3	Fentanyl	Fentanyl	Fentanyl	Fentanyl	Fentanyl	Fentanyl
Heroin	**Day 1**	Heroin	Heroin	Heroin	Heroin	Heroin	Heroin
	Day 2	Heroin	Heroin	Heroin	Heroin	Heroin	Heroin
	Day 3	Heroin	Heroin	Heroin	Heroin	Heroin	Heroin
Hydrocodone Bitartrate*	**Day 1**	Inconclusive	Inconclusive	Inconclusive	Hydrocodone	Hydrocodone	Hydrocodone
	Day 2	Inconclusive H kit: Inconclusive	Inconclusive H kit: Inconclusive	Inconclusive H kit: Inconclusive	Hydrocodone	Hydrocodone	Hydrocodone
	Day 3	---	---	---	Hydrocodone	Hydrocodone	Hydrocodone
Hydromorphone Dipottasium	**Day 1**	Hydromorphone	Hydromorphone	Hydromorphone	Hydromorphone	Hydromorphone	Hydromorphone
	Day 2	Hydromorphone	Hydromorphone	Hydromorphone	Heroin	Heroin	Hydromorphone
	Day 3	Hydromorphone	Hydromorphone	Hydromorphone	Hydromorphone	Hydromorphone	Hydromorphone
Methadone HCl	**Day 1**	Methadone	Methadone	Methadone	Methadone	Methadone	Methadone
	Day 2	Methadone	Methadone	Methadone	Methadone	Methadone	Methadone
	Day 3	Methadone	Methadone	Methadone	Methadone	Methadone	Methadone
Meth HCl	**Day 1**	Meth	Meth	Meth	Meth	Meth	Meth
	Day 2	Meth	Meth	Meth	Meth	Meth	Meth
	Day 3	Meth	Meth	Meth	Meth	Meth	Meth
Methylone HCl	**Day 1**	Methylone	Methylone	Methylone	Methylone	Methylone	Methylone
	Day 2	Methylone	Methylone	Methylone	Methylone	Methylone	Methylone
	Day 3	Methylone	Methylone	Methylone	Methylone	Methylone	Methylone
MDMA HCl	**Day 1**	MDMA	MDMA	MDMA	MDMA	MDMA	MDMA
	Day 2	MDMA	MDMA	MDMA	MDMA	MDMA	MDMA
	Day 3	MDMA	MDMA	MDMA	MDMA	MDMA	MDMA
Oxycodone HCl	**Day 1**	Oxycodone	Oxycodone	Oxycodone	Oxycodone	Oxycodone	Oxycodone
	Day 2	Oxycodone	Oxycodone	Oxycodone	Oxycodone	Oxycodone	Oxycodone
	Day 3	Oxycodone	Oxycodone	Oxycodone	Oxycodone	Oxycodone	Oxycodone
α-PVP HCl	**Day 1**	α-PVP	α-PVP	α-PVP	α-PVP	α-PVP	α-PVP
	Day 2	α-PVP	α-PVP	α-PVP	α-PVP	α-PVP	α-PVP
	Day 3	α-PVP	α-PVP	α-PVP	α-PVP	α-PVP	α-PVP

*Scans were not completed once discovered hydrocodone was not in company's library.

Appendix B

Table 11. TruNarc® accuracy results for each case sample scanned in triplicate[++].

Drugs Identified by Laboratory Analysis	Number of scans	Number of TruNarc Positive Identifications for Drug of Interest	Misidentification of drug	Number of Inconclusive Results	Other Components Identified	Was the H kit used?	Comments
α-PVP	15	6	0	9	0	No	
Alprazolam**	81	80	0	1	0	Yes	
Acetaminophen and Propoxyphene napsylate (650/100 mg tablet)	9	0	0	0	9	No	Acetaminophen-9
Benzocaine Caffeine	9	9*	0	0	0	No	Benzocaine and Caffeine-7 Benzocaine-2
BZP TFMPP	30	27*	0	3	0	No	BZP-27
BTCP Ethylone MDPV	3	0	3	0	0	No	MDPBP-3 BTCP not in library
BTCP BZP TFMPP 5MeO-DiPT	6	4*	1	0	1	No	Caffeine-1 TFMPP-4 Methylamine HCl-1 BTCP not in library
Calcium Carbonate	9	9	0	0	0	No	
Clonazepam	9	9	0	0	0	No	
Cocaine	246	243	0	0	3	No	Benzocaine-3
Fentanyl	9	0	0	6	3	No	Mannitol-3
Heroin	81	36	0	45	0	Yes+	
Hydromorphone	54	15	0	17	22	Yes[+]	Lactose-22
Methadone	27	17	1	9	0	No	Fentanyl-1
Methamphetamine	3	1	0	0	2	No	Caffeine-2
Methamphetamine MDMA	63	28*	0	8	27	Yes[+]	Meth and MDMA-4 MDMA-22 Meth-2 Caffeine-27
MDMA	48	33	0	6	9	Yes[+]	Caffeine-9
Oxycodone	99	99	0	0	0	No	
Procaine	3	0	0	3	0	No	
Quinine	3	0	0	3	0	No	
Suspected Glass (Silicon Dioxide)	3	3	0	0	0	No	
Tramadol	18	18	0	0	0	No	
TOTAL	**828**	**637**	**5**	**110**	**76**		

*Identified one or more components of the mixture. **Initial scans without the Type H kit are not included.

[+] The H kit was used in some cases after initial scans when the target drug was assumed to be in low concentrations.

[++]These totals include all casework samples. Note: some were not rescanned on days two and three.

Table 12. PGR-1064® accuracy results for each case sample scanned in triplicate+.

Drugs Identified by Laboratory Analysis	Number of scans	Number of PGR-1064 Positive Identifications for Drug of Interest	Misidentification of drug	Number of Unidentified Results	Other Components Identified	Comments
α-PVP	15	4	4	7	0	MDPV-3 Diethylcathinone-1
Acetaminophen and Hydrocodone (500/5 mg tablet)	18	0	0	0	18*	Acetaminophen-18
Acetaminophen and Propoxyphene napsylate (650/100 mg tablet)	9	0	0	0	9*	Acetaminophen-9
Alprazolam	81	0	0	1	80	Lactose-64 Cellulose-15 Lactose and Cellulose-1
Benzocaine and Caffeine	9	9*	0	0	0	Benzocaine-9
BTCP Ethylone MDPV	3	2*	0	1	0	MDPV-2
BTCP BZP TFMPP 5MeO-DiPT	6	0	0	0	6	Caffeine-6
BZP and TFMPP	30	2*	0	25	3	BZP-2 Caffeine-3
Calcium Carbonate	9	0	0	7	2	Dextrose-2
Clonazepam	9	0	0	0	9	Lactose-8 Cellulose-1
Cocaine	246	239	0	0	7	Benzocaine-7
Fentanyl	9	0	0	9	0	
Heroin	45	11	0	19	15	Caffeine-3 Quinine-11 Lactose-1
Hydromorphone	36	0	0	0	36	Lactose-36
Methadone	27	1	2	6	18	Cellulose-9 Lactose-9 Temazepam-1 Diazepam-1
Methamphetamine	3	0	0	0	3	Caffeine-3
Methamphetamine and MDMA	36	1*	0	0	35	Caffeine-35 MDMA-1
MDMA	39	0	0	28	11	Lactose-2 Caffeine-9
Oxycodone	99	1	0	55	43	Lactose-31 Sucrose-5 Mineral Oils-3 Zinc Stearate-1 Cellulose-1 Cellulose and Lactose-2
Procaine	3	0	0	3	0	
Quinine	3	3	0	0	0	
Suspected Glass (Silicon Dioxide)	3	0	0	3	0	
Tramadol	18	0	5	1	12	Cellulose-4 Temazepam-5 Lactose-8
TOTAL	**756**	**273**	**11**	**165**	**307**	

*Identified one or more components of the mixture. + These totals include all casework samples.

Table 13. A comparison of the scan results for each adjudicated case sample scanned in triplicate on days one, two and three by the TruNarc® and PGR-1064® Raman systems.

Sample Information			TruNarc S/N: TN1078			PGR 1064 S/N: 0025		
I.D	**Drugs Identified by Laboratory analysis**	**Days of Scans**	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 1**	**Trial 2**	**Trial 3**
A	Heroin Quinine Caffeine	**Day 1**	Inconclusive H kit: Heroin	Inconclusive H kit: Heroin	Inconclusive H kit: Heroin	Caffeine	Caffeine	Caffeine
		Day 2	Inconclusive H kit: Heroin	Inconclusive H kit: Heroin	Inconclusive H kit: Heroin	Quinine	Quinine	Unidentified
		Day 3	Inconclusive H kit: Heroin	Inconclusive H kit: Heroin	Inconclusive H kit: Heroin	Quinine	Unidentified	Unidentified
B	Hydromorphone (8 mg)	**Day 1**	Lactose	Lactose	Lactose	Lactose	Lactose	Lactose
		Day 2	Lactose	Hydromorphone	Lactose	Lactose	Lactose	Lactose
		Day 3	Hydromorphone	Hydromorphone	Inconclusive	Lactose	Lactose	Lactose
C	Cocaine	**Day 1**	Cocaine Base	Cocaine Base	Cocaine Base	Cocaine Freebase	Cocaine Freebase	Cocaine Freebase
		Day 2	Cocaine Base	Cocaine Base	Cocaine Base	Cocaine Freebase	Cocaine Freebase	Cocaine Freebase
		Day 3	Cocaine Base	Cocaine Base	Cocaine Base	Cocaine Freebase	Cocaine Freebase	Cocaine Freebase
D	Meth MDMA Caffeine	**Day 1**	Meth and MDMA	Meth	Meth and MDMA	Caffeine	Caffeine	Caffeine
		Day 2	Caffeine	Meth and MDMA	Meth and MDMA	Caffeine	Caffeine	Caffeine
		Day 3	Meth and MDMA	Meth	Meth and MDMA	Caffeine	Meth	Caffeine
E	Alprazolam (2 mg)	**Day 1**	Lactose and Cellulose H kit: Alprazolam	Lactose and Cellulose H kit: Alprazolam	Lactose and Cellulose H kit: Alprazolam	Lactose	Lactose	Lactose and Cellulose
		Day 2	Lactose and Cellulose H kit: Alprazolam	Lactose and Cellulose H kit: Alprazolam	Lactose and Cellulose H kit: Alprazolam	Cellulose	Lactose	Lactose
		Day 3	Lactose and Cellulose H kit: Alprazolam	Lactose and Cellulose H kit: Alprazolam	Lactose and Cellulose H kit: Alprazolam	Lactose	Lactose	Lactose
F	Heroin	**Day 1**	Inconclusive H kit: Heroin	Inconclusive H kit: Heroin	Inconclusive H kit: Heroin	Unidentified	Unidentified	Lactose
		Day 2	Inconclusive H kit: Heroin	Inconclusive *H kit: Heroin	Inconclusive H kit: Heroin	Unidentified	Heroin	Unidentified
		Day 3	Inconclusive H kit: Heroin	Inconclusive H kit: Heroin	Inconclusive H kit: Heroin	Unidentified	Unidentified	Unidentified

Sample Information			TruNarc S/N: TN1078			PGR 1064 S/N: 0025		
I.D	**Drugs Identified by Laboratory Analysis**	**Days of Scans**	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 1**	**Trial 2**	**Trial 3**
G	MDMA	**Day 1**	Inconclusive	MDMA	Inconclusive	Unidentified	Unidentified	Unidentified
		Day 2	Inconclusive	MDMA	Inconclusive	Unidentified	Unidentified	Lactose
		Day 3	MDMA	Inconclusive	Inconclusive	Unidentified	Unidentified	Lactose
H	Methadone residue	**Day 1**	Inconclusive	Inconclusive	Inconclusive	Cellulose	Cellulose	Cellulose
		Day 2	Inconclusive	Inconclusive	Inconclusive	Cellulose	Cellulose	Unidentified
		Day 3	Inconclusive	Inconclusive	Inconclusive	Unidentified	Unidentified	Cellulose
I.1	Oxycodone (30 mg)	**Day 1**	Oxycodone	Oxycodone	Oxycodone	Unidentified	Lactose	Unidentified
		Day 2	Oxycodone	Oxycodone	Oxycodone	Unidentified	Unidentified	Unidentified
		Day 3	Oxycodone	Oxycodone	Oxycodone	Lactose	Lactose	Unidentified
I.2	Acetaminophen and Hydrocodone tablet (500/5mg)	**Day 1**	Acetaminophen	Acetaminophen	Acetaminophen	Acetaminophen	Acetaminophen	Acetaminophen
		Day 2	Acetaminophen	Acetaminophen	Acetaminophen	Acetaminophen	Acetaminophen	Acetaminophen
		Day 3	Acetaminophen	Acetaminophen	Acetaminophen	Acetaminophen	Acetaminophen	Acetaminophen
I.3	Acetaminophen and propoxyphene napsylate tablet (650/100 mg)	**Day 1**	Acetaminophen	Acetaminophen	Acetaminophen	Acetaminophen	Acetaminophen	Acetaminophen
		Day 2	Acetaminophen	Acetaminophen	Acetaminophen	Acetaminophen	Acetaminophen	Acetaminophen
		Day 3	Acetaminophen	Acetaminophen	Acetaminophen	Acetaminophen	Acetaminophen	Acetaminophen
J	Alprazolam (2 mg)	**Day 1**	Lactose and Cellulose H kit: Alprazolam	Lactose and Cellulose H kit: Alprazolam	Lactose and Cellulose H kit: Alprazolam	Lactose	Cellulose	Lactose
		Day 2	Lactose and Cellulose H kit: Alprazolam	Lactose and Cellulose H kit: Alprazolam	Lactose and Cellulose H kit: Alprazolam	Lactose	Lactose	Lactose
		Day 3	Lactose and Cellulose H kit: Alprazolam	Lactose and Cellulose H kit: Alprazolam	Lactose and Cellulose H kit: Alprazolam	Cellulose	Lactose	Lactose
K.1	Oxycodone (30 mg)	**Day 1**	Oxycodone	Oxycodone	Oxycodone	Lactose	Lactose	Unidentified
		Day 2	Oxycodone	Oxycodone	Oxycodone	Unidentified	Unidentified	Unidentified
		Day 3	Oxycodone	Oxycodone	Oxycodone	Unidentified	Lactose	Lactose
K.2	Oxycodone (40 mg)	**Day 1**	Oxycodone	Oxycodone	Oxycodone	Mineral Oils	Unidentified	Sucrose
		Day 2	Oxycodone	Oxycodone	Oxycodone	Sucrose	Unidentified	Sucrose
		Day 3	Oxycodone	Oxycodone	Oxycodone	Zinc Stearate	Mineral Oils	Mineral Oils
K.3	Oxycodone (80 mg)	**Day 1**	Oxycodone	Oxycodone	Oxycodone	Sucrose	Unidentified	Unidentified
		Day 2	Oxycodone	Oxycodone	Oxycodone	Unidentified	Unidentified	Unidentified
		Day 3	Oxycodone	Oxycodone	Oxycodone	Sucrose	Unidentified	Unidentified

Sample Information			TruNarc S/N: TN1078			PGR 1064 S/N: 0025		
I.D	**Drugs Identified by Laboratory Analysis**	**Days of Scans**	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 1**	**Trial 2**	**Trial 3**
K.4	Calcium Carbonate (500 mg)	**Day 1**	Calcium Carbonate	Calcium Carbonate	Calcium Carbonate	Unidentified	Dextrose	Unidentified
		Day 2	Calcium Carbonate	Calcium Carbonate	Calcium Carbonate	Unidentified	Unidentified	Unidentified
		Day 3	Calcium Carbonate	Calcium Carbonate	Calcium Carbonate	Unidentified	Unidentified	Dextrose
K.5	Tramadol (50 mg)	**Day 1**	Tramadol	Tramadol	Tramadol	Cellulose	Temazepam	Cellulose
		Day 2	Tramadol	Tramadol	Tramadol	Cellulose	Temazepam	Temazepam
		Day 3	Tramadol	Tramadol	Tramadol	Temazepam	Cellulose	Temazepam
L	Oxycodone (30 mg)	**Day 1**	Oxycodone	Oxycodone	Oxycodone	Lactose	Lactose	Lactose
		Day 2	Oxycodone	Oxycodone	Oxycodone	Unidentified	Unidentified	Lactose
		Day 3	Oxycodone	Oxycodone	Oxycodone	Lactose	Lactose	Lactose
M.1	Oxycodone (30 mg)	**Day 1**	Oxycodone	Oxycodone	Oxycodone	Unidentified	Cellulose	Unidentified
		Day 2	Oxycodone	Oxycodone	Oxycodone	Lactose	Unidentified	Unidentified
		Day 3	Oxycodone	Oxycodone	Oxycodone	Lactose	Lactose	Lactose
M.2	Oxycodone (30 mg)	**Day 1**	Oxycodone	Oxycodone	Oxycodone	Lactose	Unidentified	Lactose
		Day 2	Oxycodone	Oxycodone	Oxycodone	Cellulose	Unidentified	Cellulose
		Day 3	Oxycodone	Oxycodone	Oxycodone	Lactose	Lactose	Lactose
N.1	Alprazolam (2 mg)	**Day 1**	Lactose H kit: Alprazolam	Lactose H kit: Alprazolam	Lactose H kit: Alprazolam	Lactose	Lactose	Lactose
		Day 2	Lactose H kit: Alprazolam	Lactose H kit: Alprazolam	Lactose H kit: Alprazolam	Lactose	Lactose	Lactose
		Day 3	Lactose H kit: Alprazolam	Lactose H kit: Alprazolam	Lactose H kit: Alprazolam	Lactose	Lactose	Lactose
N.2	Alprazolam (2 mg)	**Day 1**	Lactose H kit: Alprazolam	Lactose H kit: Alprazolam	Lactose H kit: Alprazolam	Lactose	Lactose	Lactose
		Day 2	Lactose and Cellulose H kit: Alprazolam	Lactose and Cellulose H kit: Alprazolam	Lactose and Cellulose H kit: Alprazolam	Lactose	Lactose	Lactose
		Day 3	Lactose and Cellulose H kit: Alprazolam	Lactose H kit: Alprazolam	Lactose and Cellulose H kit: Alprazolam	Cellulose	Unidentified	Lactose
O	Cocaine	**Day 1**	Cocaine Base	Cocaine Base	Cocaine Base	Cocaine Freebase	Cocaine Freebase	Cocaine Freebase
		Day 2	Cocaine Base	Cocaine Base	Cocaine Base	Cocaine Freebase	Cocaine Freebase	Cocaine Freebase
		Day 3	Cocaine Base	Cocaine Base	Cocaine Base	Cocaine Freebase	Cocaine Freebase	Cocaine Freebase
P.1	Cocaine Benzocaine	**Day 1**	Cocaine Base	Cocaine Base	Cocaine Base	Cocaine Freebase	Cocaine Freebase	Cocaine Freebase
		Day 2	Cocaine Base	Cocaine Base	Cocaine Base	Cocaine Freebase	Cocaine Freebase	Cocaine Freebase
		Day 3	Cocaine Base	Cocaine Base	Cocaine Base	Cocaine Freebase	Cocaine Freebase	Cocaine Freebase
P.2	Cocaine Benzocaine	**Day 1**	Cocaine Base	Cocaine Base	Cocaine Base	Benzocaine	Benzocaine	Benzocaine
		Day 2	Benzocaine	Cocaine Base	Cocaine Base	Benzocaine	Benzocaine	Cocaine Freebase
		Day 3	Benzocaine	Benzocaine	Cocaine Base	Benzocaine	Benzocaine	Cocaine Freebase

Sample Information			TruNarc S/N: TN1078			PGR 1064 S/N: 0025		
I.D	**Drugs Identified by Laboratory Analysis**	**Days of Scans**	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 1**	**Trial 2**	**Trial 3**
Q.1	Cocaine Levamisole	**Day 1**	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl
		Day 2	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl
		Day 3	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl
Q.2	Cocaine Levamisole	**Day 1**	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl
		Day 2	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl
		Day 3	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl
Q.3	Alprazolam (2 mg)	**Day 1**	Lactose H kit: Alprazolam	Lactose H kit: Alprazolam	Lactose H kit: Alprazolam	Lactose	Lactose	Lactose
		Day 2	Lactose H kit: Alprazolam	Lactose H kit: Alprazolam	Lactose H kit: Alprazolam	Lactose	Lactose	Lactose
		Day 3	Lactose H kit: Alprazolam	Lactose H kit: Alprazolam	Lactose H kit: Alprazolam	Lactose	Lactose	Lactose
R	Cocaine	**Day 1**	Cocaine Base	Cocaine Base	Cocaine Base	Cocaine Freebase	Cocaine Freebase	Cocaine Freebase
		Day 2	Cocaine Base	Cocaine Base	Cocaine Base	Cocaine Freebase	Cocaine Freebase	Cocaine Freebase
		Day 3	Cocaine Base	Cocaine Base	Cocaine Base	Cocaine Freebase	Cocaine Freebase	Cocaine Freebase
S	Cocaine	**Day 1**	Cocaine Base	Cocaine Base	Cocaine Base	Cocaine Freebase	Cocaine Freebase	Cocaine Freebase
		Day 2	Cocaine Base	Cocaine Base	Cocaine Base	Cocaine Freebase	Cocaine Freebase	Cocaine Freebase
		Day 3	Cocaine Base	Cocaine Base	Cocaine Base	Cocaine Freebase	Cocaine Freebase	Cocaine Freebase
T	Hydromorphone (8 mg)	**Day 1**	Lactose H kit: Inconclusive	Lactose H kit: Hydromorphone	Lactose H kit: Inconclusive	Lactose	Lactose	Lactose
		Day 2	Lactose H kit: Inconclusive	Lactose H kit: Hydromorphone and Fentanyl	Lactose H kit: Inconclusive	Lactose	Lactose	Lactose
		Day 3	Lactose H kit: Inconclusive	Hydromorphone H kit: Inconclusive	Lactose H kit: Inconclusive	Lactose	Lactose	Lactose
U	Hydromorphone (8 mg)	**Day 1**	Lactose H kit: Inconclusive	Lactose H kit: Inconclusive	Lactose H kit: Inconclusive	Lactose	Lactose	Lactose
		Day 2	Lactose H kit: Inconclusive	Hydromorphone H kit: Inconclusive	Lactose H kit: Inconclusive	Lactose	Lactose	Lactose
		Day 3	Lactose H kit: Inconclusive	Lactose H kit: Inconclusive	Lactose H kit: Inconclusive	Lactose	Lactose	Lactose
V	Clonazepam (2 mg)	**Day 1**	Clonazepam	Clonazepam	Clonazepam	Lactose	Lactose	Lactose
		Day 2	Clonazepam	Clonazepam	Clonazepam	Lactose	Lactose	Lactose
		Day 3	Clonazepam	Clonazepam	Clonazepam	Lactose	Lactose	Cellulose

Sample Information			TruNarc S/N: TN1078			PGR 1064 S/N: 0025		
I.D	**Drugs Identified by Laboratory analysis**	**Days of Scans**	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 1**	**Trial 2**	**Trial 3**
W.1	Alprazolam (2 mg)	**Day 1**	Cellulose H kit: Alprazolam	Cellulose H kit: Alprazolam	Cellulose H kit: Alprazolam	Cellulose	Cellulose	Cellulose
		Day 2	Cellulose H kit: Alprazolam	Cellulose H kit: Alprazolam	Cellulose H kit: Alprazolam	Cellulose	Cellulose	Cellulose
		Day 3	Cellulose H kit: Alprazolam	Cellulose H kit: Alprazolam	Cellulose H kit: Inconclusive	Cellulose	Cellulose	Cellulose
W.2	MDMA	**Day 1**	MDMA	MDMA	MDMA	Unidentified	Unidentified	Unidentified
		Day 2	MDMA	MDMA	MDMA	Unidentified	Unidentified	Unidentified
		Day 3	MDMA	MDMA	MDMA	Unidentified	Unidentified	Unidentified
X	Hydromorphone (8 mg)	**Day 1**	Hydromorphone	Hydromorphone	Hydromorphone	Lactose	Lactose	Lactose
		Day 2	Hydromorphone	Hydromorphone	Hydromorphone	Lactose	Lactose	Lactose
		Day 3	Hydromorphone	Hydromorphone	Hydromorphone	Lactose	Lactose	Lactose
Y	Heroin Quinine Mannitol	**Day 1**	Inconclusive H kit: Heroin	Inconclusive H kit: Heroin	Inconclusive H kit: Heroin	Heroin	Quinine	Quinine
		Day 2	Inconclusive H kit: Heroin	Inconclusive H kit: Heroin	Inconclusive H kit: Heroin	Quinine	Quinine	Quinine
		Day 3	Inconclusive H kit: Heroin	Inconclusive H kit: Heroin	Inconclusive H kit: Heroin	Quinine	Quinine	Quinine
Z	Heroin 6 MAM Acetylcodeine Mannitol	**Day 1**	Inconclusive H kit: Heroin	Inconclusive H kit: Heroin	Inconclusive H kit: Heroin	Unidentified	Unidentified	Unidentified
		Day 2	Inconclusive H kit: Heroin	Inconclusive H kit: Heroin	Inconclusive H kit: Heroin	Unidentified	Unidentified	Unidentified
		Day 3	Inconclusive H kit: Heroin	Inconclusive H kit: Heroin	Inconclusive H kit: Heroin	Unidentified	Unidentified	Unidentified
AA.1	Acetaminophen/ Hydrocodone tablet (500/5 mg)	**Day 1**	Acetaminophen	Acetaminophen	Acetaminophen	Acetaminophen	Acetaminophen	Acetaminophen
		Day 2	Acetaminophen	Acetaminophen	Acetaminophen	Acetaminophen	Acetaminophen	Acetaminophen
		Day 3	Acetaminophen	Acetaminophen	Acetaminophen	Acetaminophen	Acetaminophen	Acetaminophen
AA.2	Tramadol (50 mg)	**Day 1**	Tramadol	Tramadol	Tramadol	Lactose	Lactose	Lactose
		Day 2	Tramadol	Tramadol	Tramadol	Lactose	Lactose	Lactose
		Day 3	Tramadol	Tramadol	Tramadol	Lactose	Unidentified	Lactose
BB.1	Alprazolam (2 mg)	**Day 1**	Lactose H kit: Alprazolam	Lactose H kit: Alprazolam	Lactose H kit: Alprazolam	Lactose	Lactose	Lactose
		Day 2	Lactose H kit: Alprazolam	Lactose H kit: Alprazolam	Lactose H kit: Alprazolam	Lactose	Lactose	Lactose
		Day 3	Lactose H kit: Alprazolam	Lactose H kit: Alprazolam	Lactose H kit: Alprazolam	Lactose	Lactose	Lactose

Sample Information			TruNarc S/N: TN1078			PGR 1064 S/N: 0025		
I.D	**Drugs Identified by Laboratory analysis**	**Days of Scans**	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 1**	**Trial 2**	**Trial 3**
BB.2	MDMA	**Day 1**	Caffeine H kit: MDMA	Caffeine H kit: MDMA	Caffeine H kit: MDMA	Caffeine	Caffeine	Caffeine
		Day 2	Caffeine H kit: MDMA	Caffeine H kit: MDMA	Caffeine H kit: MDMA	Caffeine	Caffeine	Caffeine
		Day 3	Caffeine H kit: MDMA	Caffeine H kit: MDMA	Caffeine H kit: MDMA	Caffeine	Caffeine	Caffeine
BB.3	Oxycodone (80 mg)	**Day 1**	Oxycodone	Oxycodone	Oxycodone	Unidentified	Unidentified	Unidentified
		Day 2	Oxycodone	Oxycodone	Oxycodone	Unidentified	Unidentified	Unidentified
		Day 3	Oxycodone	Oxycodone	Oxycodone	Unidentified	Unidentified	Unidentified
CC	MDMA	**Day 1**	MDMA	MDMA	MDMA	Unidentified	Unidentified	Unidentified
		Day 2	MDMA	MDMA	MDMA	Unidentified	Unidentified	Unidentified
		Day 3	MDMA	MDMA	MDMA	Unidentified	Unidentified	Unidentified
DD.1	Alprazolam (2 mg)	**Day 1**	Lactose H kit: Alprazolam	Lactose H kit: Alprazolam	Lactose H kit: Alprazolam	Lactose	Lactose	Lactose
		Day 2	Lactose H kit: Alprazolam	Lactose H kit: Alprazolam	Lactose H kit: Alprazolam	Lactose	Lactose	Lactose
		Day 3	Lactose H kit: Alprazolam	Lactose H kit: Alprazolam	Lactose H kit: Alprazolam	Lactose	Lactose	Lactose
DD.2	Alprazolam (2 mg)	**Day 1**	Lactose and Cellulose H kit: Alprazolam	Lactose and Cellulose H kit: Alprazolam	Lactose and Cellulose H kit: Alprazolam	Cellulose	Lactose	Lactose
		Day 2	Lactose and Cellulose H kit: Alprazolam	Lactose and Cellulose H kit: Alprazolam	Lactose and Cellulose H kit: Alprazolam	Lactose	Lactose	Lactose
		Day 3	Lactose and Cellulose H kit: Alprazolam	Lactose and Cellulose H kit: Alprazolam	Lactose and Cellulose H kit: Alprazolam	Cellulose	Lactose	Lactose
DD.3	Methadone (10 mg)	**Day 1**	Methadone	Methadone	Methadone	Methadone	Cellulose	Cellulose
		Day 2	Methadone	Methadone	Methadone	Cellulose	Cellulose	Temazepam
		Day 3	Methadone	Methadone	Methadone	Cellulose	Cellulose	Diazepam
DD.4	Methadone (10 mg)	**Day 1**	Methadone	Methadone	Methadone	Lactose	Lactose	Lactose
		Day 2	Methadone	Methadone	Methadone	Lactose	Lactose	Lactose
		Day 3	Fentanyl	Methadone	Methadone	Lactose	Lactose	Lactose
DD.5	Oxycodone (80 mg)	**Day 1**	Oxycodone	Oxycodone	Oxycodone	Unidentified	Unidentified	Lactose
		Day 2	Oxycodone	Oxycodone	Oxycodone	Unidentified	Unidentified	Unidentified
		Day 3	Oxycodone	Oxycodone	Oxycodone	Unidentified	Unidentified	Unidentified
DD.6	Oxycodone (30 mg)	**Day 1**	Oxycodone	Oxycodone	Oxycodone	Oxycodone	Unidentified	Unidentified
		Day 2	Oxycodone	Oxycodone	Oxycodone	Unidentified	Unidentified	Unidentified
		Day 3	Oxycodone	Oxycodone	Oxycodone	Unidentified	Unidentified	Unidentified
DD.7	Oxycodone (30 mg)	**Day 1**	Oxycodone	Oxycodone	Oxycodone	Lactose	Unidentified	Lactose
		Day 2	Oxycodone	Oxycodone	Oxycodone	Lactose	Lactose	Lactose
		Day 3	Oxycodone	Oxycodone	Oxycodone	Lactose	Lactose	Unidentified

Sample Information			TruNarc S/N: TN1078			PGR 1064 S/N: 0025		
I.D	**Drugs identified by laboratory analysis**	**Days of Scans**	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 1**	**Trial 2**	**Trial 3**
EE	Cocaine	**Day 1**	Cocaine Base	Cocaine Base	Cocaine Base	Cocaine Freebase	Cocaine Freebase	Cocaine Freebase
		Day 2	Cocaine Base	Cocaine Base	Cocaine Base	Cocaine Freebase	Cocaine Freebase	Cocaine Freebase
		Day 3	Cocaine Base	Cocaine Base	Cocaine Base	Cocaine Freebase	Cocaine Freebase	Cocaine Freebase
FF	Cocaine	**Day 1**	Cocaine Base	Cocaine Base	Cocaine Base	Cocaine Freebase	Cocaine Freebase	Cocaine Freebase
		Day 2	Cocaine Base	Cocaine Base	Cocaine Base	Cocaine Freebase	Cocaine Freebase	Cocaine Freebase
		Day 3	Cocaine Base	Cocaine Base	Cocaine Base	Cocaine Freebase	Cocaine Freebase	Cocaine Freebase
GG	Cocaine	**Day 1**	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl
		Day 2	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl
		Day 3	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl
HH.1	Meth MDMA Caffeine	**Day 1**	Caffeine H kit: MDMA	Caffeine H kit: MDMA	Caffeine H kit: MDMA	Caffeine	Caffeine	Caffeine
		Day 2	Caffeine H kit: MDMA	Caffeine H kit: MDMA	Caffeine H kit: MDMA	Caffeine	Caffeine	Caffeine
		Day 3	Caffeine H kit: MDMA	Caffeine H kit: MDMA	Caffeine H kit: MDMA	Caffeine	Caffeine	Caffeine
HH.2	Meth MDMA Caffeine	**Day 1**	Caffeine H kit: Inconclusive	Caffeine H kit: Inconclusive	Caffeine H kit: Inconclusive	Caffeine	Caffeine	Caffeine
		Day 2	Caffeine H kit: Inconclusive	Caffeine H kit: Inconclusive	Caffeine H kit: Inconclusive	Caffeine	Caffeine	Caffeine
		Day 3	Caffeine H kit: Inconclusive	Caffeine H kit: Inconclusive	Caffeine H kit: MDMA	Caffeine	Caffeine	Caffeine
HH.3	Meth MDMA Caffeine	**Day 1**	Caffeine H kit: MDMA	Caffeine H kit: MDMA	Caffeine H kit: MDMA	Caffeine	Caffeine	Caffeine
		Day 2	Caffeine H kit: MDMA	Caffeine H kit: MDMA	Caffeine H kit: MDMA	Caffeine	Caffeine	Caffeine
		Day 3	Caffeine H kit: MDMA	Caffeine H kit: MDMA	Caffeine H kit: MDMA	Caffeine	Caffeine	Caffeine
II.1	Benzocaine Caffeine	**Day 1**	Benzocaine and Caffeine	Benzocaine and Caffeine	Benzocaine and Caffeine	Benzocaine	Benzocaine	Benzocaine
		Day 2	Benzocaine and Caffeine	Benzocaine	Benzocaine	Benzocaine	Benzocaine	Benzocaine
		Day 3	Benzocaine and Caffeine	Benzocaine and Caffeine	Benzocaine and Caffeine	Benzocaine	Benzocaine	Benzocaine
II.2	Cocaine	**Day 1**	Cocaine Base	Cocaine Base	Cocaine Base	Cocaine Freebase	Cocaine Freebase	Cocaine Freebase
		Day 2	Cocaine Base	Cocaine Base	Cocaine Base	Cocaine Freebase	Cocaine Freebase	Cocaine Freebase
		Day 3	Cocaine Base	Cocaine Base	Cocaine Base	Cocaine Freebase	Cocaine Freebase	Cocaine Freebase
II.3	BZP TFMPP Caffeine	**Day 1**	BZP	BZP	BZP	Unidentified	Unidentified	Unidentified
		Day 2	BZP	BZP	BZP	Unidentified	Unidentified	Unidentified
		Day 3	BZP	BZP	BZP	Unidentified	Unidentified	Unidentified
II.4	BZP TFMPP Caffeine	**Day 1**	BZP	BZP	BZP	BZP	BZP	Unidentified
		Day 2	BZP	BZP	BZP	Unidentified	Unidentified	Unidentified
		Day 3	BZP	BZP	BZP	Unidentified	Unidentified	Unidentified
II.5	BZP TFMPP Caffeine	**Day 1**	BZP	BZP	BZP	Unidentified	Unidentified	Unidentified
		Day 2	BZP	BZP	BZP	Unidentified	Unidentified	Unidentified
		Day 3	BZP	BZP	BZP	Unidentified	Unidentified	Unidentified

Sample Information			TruNarc S/N: TN1078			PGR 1064 S/N: 0025		
I.D	**Drugs identified by laboratory analysis**	**Days of Scans**	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 1**	**Trial 2**	**Trial 3**
JJ.1	Cocaine	**Day 1**	Cocaine Base	Cocaine Base	Cocaine Base	Cocaine Freebase	Cocaine Freebase	Cocaine Freebase
		Day 2	Cocaine Base	Cocaine Base	Cocaine Base	Cocaine Freebase	Cocaine Freebase	Cocaine Freebase
		Day 3	Cocaine Base	Cocaine Base	Cocaine Base	Cocaine Freebase	Cocaine Freebase	Cocaine Freebase
JJ.2	Cocaine Procaine	**Day 1**	Cocaine Base	Cocaine Base	Cocaine Base	Cocaine Freebase	Cocaine Freebase	Cocaine Freebase
		Day 2	Cocaine Base	Cocaine Base	Cocaine Base	Cocaine Freebase	Cocaine Freebase	Cocaine Freebase
		Day 3	Cocaine Base	Cocaine Base	Cocaine Base	Cocaine Freebase	Cocaine Freebase	Cocaine Freebase
KK	Cocaine	**Day 1**	Cocaine Base	Cocaine Base	Cocaine Base	Cocaine Freebase	Cocaine Freebase	Cocaine Freebase
		Day 2	Cocaine Base	Cocaine Base	Cocaine Base	Cocaine Freebase	Cocaine Freebase	Cocaine Freebase
		Day 3	Cocaine Base	Cocaine Base	Cocaine Base	Cocaine Freebase	Cocaine Freebase	Cocaine Freebase
LL	Cocaine	**Day 1**	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl
		Day 2	Cocaine Base	Cocaine Base and HCl	Cocaine Base and HCl	Cocaine Base	Cocaine Base	Cocaine HCl
		Day 3	Cocaine Base	Cocaine HCl	Cocaine HCl	Cocaine Base	Cocaine HCl	Cocaine HCl
MM	Cocaine	**Day 1**	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl
		Day 2	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl
		Day 3	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl
NN	Cocaine	**Day 1**	Cocaine Base	Cocaine Base	Cocaine Base	Cocaine Freebase	Cocaine Freebase	Cocaine Freebase
		Day 2	Cocaine Base	Cocaine Base	Cocaine Base	Cocaine Freebase	Cocaine Freebase	Cocaine Freebase
		Day 3	Cocaine Base	Cocaine Base	Cocaine Base	Cocaine Freebase	Cocaine Freebase	Cocaine Freebase

Table 14. A comparison of the scan results for each non-adjudicated case sample scanned in triplicate by the TruNarc® and PGR-1064® Raman systems*.

Sample Information			TruNarc S/N: TN1078			PGR 1064 S/N: 0025		
I.D	**Drugs identified by laboratory analysis**	**Days of Scans**	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 1**	**Trial 2**	**Trial 3**
OO.1	BTCP Ethylone MDPV Caffeine	**Day 1**	MDPBP	MDPBP	MDPBP	MDPV	MDPV	Unidentified
OO.2	5MeO-DiPT BTCP BZP TFMPP Caffeine Pseudoephedrine	**Day 1**	Caffeine	TFMPP	TFMPP	Caffeine	Caffeine	Caffeine
OO.3	5MeO-DiPT BTCP BZP TFMPP Caffeine Pseudoephedrine	**Day 1**	TFMPP	TFMPP	Methylamine HCl	Caffeine	Caffeine	Caffeine
PP	BZP TFMPP Caffeine	**Day 1**	Inconclusive	Inconclusive	Inconclusive	Caffeine	Caffeine	Caffeine
QQ	Fentanyl Caffeine Quinine	**Day 1**	Inconclusive	Inconclusive	Inconclusive	Unidentified	Unidentified	Unidentified
RR	Fentanyl Mannitol	**Day 1**	Mannitol	Mannitol	Mannitol	Unidentified	Unidentified	Unidentified
SS	MDMA	**Day 1**	MDMA	MDMA	MDMA	Unidentified	Unidentified	Unidentified
TT	α-PVP Caffeine	**Day 1**	Inconclusive	Inconclusive	Inconclusive	Unidentified	Unidentified	Unidentified
UU	Fentanyl Procaine	**Day 1**	Inconclusive	Inconclusive	Inconclusive	Unidentified	Unidentified	Unidentified
VV	α-PVP	**Day 1**	Inconclusive	Inconclusive	Inconclusive	MDPV	MDPV	MDPV
WW	α-PVP	**Day 1**	α-PVP	α-PVP	α-PVP	Diethylcathinone	α-PVP	α-PVP
XX	α-PVP	**Day 1**	Inconclusive	Inconclusive	Inconclusive	Unidentified	Unidentified	Unidentified
YY	α-PVP	**Day 1**	α-PVP	α-PVP	α-PVP	Unidentified	α-PVP	α-PVP
ZZ	Methamphetamine	**Day 1**	Meth	Caffeine	Caffeine	Caffeine	Caffeine	Caffeine
AAA	Quinine	**Day 1**	Inconclusive	Inconclusive	Inconclusive	Quinine	Quinine	Quinine
BBB	Procaine	**Day 1**	Inconclusive	Inconclusive	Inconclusive	Unidentified	Unidentified	Unidentified
CCC	Suspected Glass	**Day 1**	Silicon Dioxide	Silicon Dioxide	Silicon Dioxide	Unidentified	Unidentified	Unidentified
DDD	Heroin core sample	**Day 1**	Inconclusive	Inconclusive	Inconclusive	Heroin	Heroin	Heroin
EEE	Cocaine core sample	**Day 1**	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl
FFF	Cocaine core sample	**Day 1**	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl
GGG	Cocaine core sample	**Day 1**	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl
HHH	Cocaine core sample	**Day 1**	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl
III	Cocaine core sample	**Day 1**	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl
JJJ	Cocaine core sample	**Day 1**	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl
KKK	Cocaine core sample	**Day 1**	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl
LLL	Cocaine core sample	**Day 1**	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl
MMM	Cocaine core sample	**Day 1**	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl
NNN	Cocaine core sample	**Day 1**	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl

Sample Information			TruNarc S/N: TN1078			PGR 1064 S/N: 0025		
I.D	**Drugs identified by laboratory analysis**	**Days of Scans**	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 1**	**Trial 2**	**Trial 3**
OOO	Cocaine core sample	Day 1	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl
PPP	Cocaine core sample	Day 1	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl
QQQ	Heroin core sample	Day 1	Inconclusive	Inconclusive	Inconclusive	Heroin	Heroin	Heroin
RRR	Heroin core sample	Day 1	Inconclusive	Inconclusive	Inconclusive	Heroin	Heroin	Heroin
SSS	Cocaine core sample	Day 1	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl
TTT	Cocaine core sample	Day 1	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl
UUU	Cocaine core sample	Day 1	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl
VVV	Cocaine core sample	Day 1	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl
WWW	Cocaine core sample	Day 1	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl
XXX	Cocaine core sample	Day 1	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl
YYY	Cocaine core sample	Day 1	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl
ZZZ	Cocaine core sample	Day 1	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl
AAAA	Cocaine core sample	Day 1	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl
BBBB	Cocaine core sample	Day 1	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl
CCCC	Cocaine core sample	Day 1	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl
DDDD	Cocaine core sample	Day 1	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl
EEEE	Cocaine core sample	Day 1	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl
FFFF	Cocaine core sample	Day 1	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl
GGGG	Cocaine core sample	Day 1	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl
HHHH	Cocaine core sample	Day 1	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl	Cocaine HCl

*****These case samples were not rescanned on days two and three.

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