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Forensic Chemical Analysis of Synthetic Cathinones Using Portable Mass Spectrometric Instrumentation: A Review

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Abstract

Forensic laboratories face issues with large backlogs on evidence needing to be analyzed due to two reasons: budgeting issues and the emergence of designer drugs. Currently, forensic laboratory directors cite that there is a shortage of scientists to deal with the yearly increase in caseloads to determine if samples are illegal. Additionally, designer drugs like synthetic cathinones, commonly known as "bath salts," have increased the backlog due to changing chemical compositions and misidentification as other compounds. Therefore, the use of a portable mass spectrometer for on-site forensic chemical analysis of synthetic cathinones would reduce the backlog of suspected controlled substances in forensic chemistry laboratories because suspected samples could be identified if illegal and needed to be sent to the laboratory for confirmation of results. A comparison of research on gas chromatography-mass spectrometry (GC-MS), typically used in forensic laboratories, and ambient mass spectrometry, an upcoming method, was conducted to determine which technique would be more suitable for on-site analysis of synthetic cathinones. Due to the spectral fragmentation caused when analyzing synthetic cathinones with GC-MS, forensic scientists should consider using ambient ionization mass spectrometry for successful identification of evidence samples. Ambient ionization mass spectrometry techniques, especially desorption electrospray ionization (DESI-MS) and direct analysis in real time (DART-MS), are also portable because of the minimum sample preparation needed and enhancement of mass spectral signals. The use of portable ambient ionization mass spectrometry techniques could potentially decrease the strain of backlogs in forensic laboratories because samples could already be identified as a suspected illegal substance and more efficiently collected for laboratory analysis.

Keywords: Synthetic Cathinones, Ambient Ionization, DESI-MS, DART-MS, GC-MS, Portable, Forensic Backlog, Designer Drugs

1. Introduction

Currently, forensic laboratories across the country, at the national, state, and local level, are experiencing an evidence testing backlog. The United States Drug Enforcement Administration (DEA) defined a backlog as the amount of samples that were unanalyzed after 30 days of submission.[1] For the backlog in forensic chemistry laboratories, a survey conducted by the DEA found that 163,806 cases, an average of 1,213 cases per laboratory, were considered backlogged in 2012.[1] For example, the Virginia Department of Forensic Science (DFS) receives over 300,000 controlled substances cases a year, contributing to the bulk of the evidence backlog and in September 2014 had 5,647 controlled substance cases backlogged with an average turnaround time of 75 days.[2] Further, the backlog in forensic chemistry laboratories is growing, as the DEA showed that drug chemistry caseloads are increasing each year.[1] These statistics show that evidence backlogs in forensic chemistry laboratories are becoming a large problem.

Forensic laboratories face issues with large backlogs on evidence needing to be analyzed due to two reasons: administrative issues and the emergence of designer drugs. First, administrative issues are a main cause for forensic laboratory backlog.[3] The main administrative issue that forensic laboratories are facing is inadequate staffing. In a survey, the DEA cited that 50% of laboratories reported that the loss of staff was a major contributor to long turnaround times on evidence requests.[1] To illustrate this point, it is estimated that one forensic scientist is needed per 30,000 people in a population, which means that state and federal laboratories need approximately 50 more scientists each to meet this standard.[4-5] While the answer may simply be hiring new scientists to deal with the shortage, forensic laboratories simply do not have the funds to do so. In fact, when forensic laboratory directors were asked what they would do with a ten percent increase in their annual budget, a majority of laboratories would hire additional employees to deal with the increase in caseload.[3] The shortage of forensic scientists is a contributing factor to the forensic evidence backlog.

Since forensic laboratory directors cite these shortages in funds to hire and train additional forensic scientists for increased backlogs, laboratories look to outsourcing. To define, outsourcing of services would be when a laboratory releases its workload to another public or private laboratory.[6] However, outsourcing a laboratory workload to another entity can create some serious legal problems. The main legal issue is that the original forensic laboratory would have a difficult time controlling the access to evidence and case files in outsourced laboratories.[3] For example, if an outsourced laboratory runs a fingerprint comparison, then there is no legal boundary preventing them from leaking criminal suspects. Therefore, outsourcing a forensic chemistry laboratory backlogs to another company is not a secure method of getting the data analyzed.

Instead, to prevent these legal issues, forensic laboratories should look to on-site analysis of evidence. Recently, crime scene investigations have been driven towards on-site analysis of evidence.[7] By analyzing the evidence in the field, forensic laboratories will have their backlogs reduced without having to look to outsourcing its workload; this also ensures the evidence collected can be defended in a court of law. Additionally, the evidence collection process would run more smoothly. Typically, crime scene investigators collect evidence based on what they suspect could be a controlled substance, for example. However, on-site analysis of evidence allows for evidence collection to proceed more efficiently and confidently because crime scene investigators could collect evidence that was already identified as a suspect sample through preliminary screening method.[8] Thus, a secure method of reducing the evidence backlog in forensic laboratories while improving evidence collection would be for the on-site analysis of suspected samples to identify if the sample should be sent for laboratory analysis.

Another reason for long analysis times on evidence samples is the emergence of "designer drugs". With the increase in usage of emerging "designer drugs," like synthetic cathinone derivatives, forensic laboratories have also seen an increase of them in evidence samples. In the DEA's 2013 survey, 61% of forensic laboratories cited emergence of "designer drugs" as a major contributor to their current backlogs.[1] These emerging "designer drugs" tend to create problems when a forensic chemistry laboratory analyzes them, causing a backlog. The influx of "designer drugs" has contributed to the forensic laboratory backlog due to their constantly changing ingredient profiles.[9] Also, the changing, unknown nature of these "designer drugs" creates a time-consuming analysis process contributing to the forensic chemistry laboratory backlogs.[10] Therefore, the recent emergence of these substances and problems with their analysis have contributed to laboratory backlogs.

Further, since synthetic cathinones continue to remain a problem for law enforcement, these compounds have also become a problem for forensic laboratories. Because of the similarities these compounds have to other derivatives within their class and other drugs, such as amphetamines, forensic laboratories cannot accurately analyze and identify these compounds using current instrumentation, commonly gas chromatography-mass spectrometry (GC-MS). By having these issues with the analysis of suspected synthetic cathinone samples, a backlog exists in forensic laboratories. However, forensic laboratories can reduce the controlled substances backlog through the use of a portable analytical technique, specifically ambient ionization mass spectrometry, which would allow for laboratories to confirm suspected drug samples.

2. Background

All synthetic cathinones share the same chemical backbone, creating the problems associated with their analysis. Synthetic cathinone derivatives are the beta-keto analogues of phenethylamine, a compound with a phenyl group attached to two carbon atoms in a linear bond, ending with an amino group.[11] Synthetic cathinones are also known as beta-keto-amphetamines due to their structural similarity to amphetamines except for the beta positioning of the ketone on the amino alkyl chain.[12] Due to the similar chemical backbone between derivatives and other drugs, errors during

the identification process occurs because these structures give similar responses to analysis.

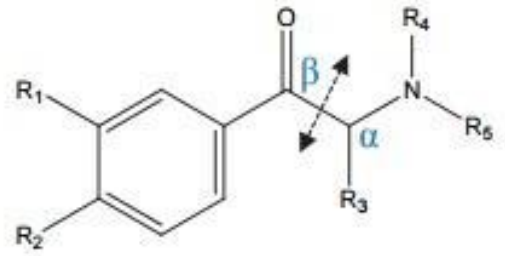

Figure 1: General structure of synthetic cathinones.[13]

Through different synthesis pathways, the diverse class of synthetic cathinones is constantly evolving through creation of new compounds with small structural differences to avoid prosecution under current legislation. Due to the different synthesis pathways and substitution placements, cathinone derivatives can be either ring substituted, alpha-carbon substituted, or N-alkylated.[13] Some common substitutions on the phenyl ring are with alkyl chains, alkoxy chains, and halogens, with each substituent being able to have a positional isomer.[14] Also, the synthesis pathway can also create synthetic cathinones with different enantiomerisms, to be specific.[15] Through these small modifications to the chemical structure by changing the chemical structure and chirality, new synthetic cathinone derivatives can be created every day, creating problems for forensic laboratories.

3. Mass Spectrometry

As for more advanced analytical techniques, forensic laboratories typically employ mass spectrometry (MS) to analyze evidence samples. MS is the most specific, sensitive, and broadly applicable out of all analytical techniques because of the information about the elemental composition of the sample, structure of the sample, and composition of complex mixtures that can be gathered.[16] Chemists are able to conclude this type of information about an evidence sample because this analytical technique studies the mass of a chemical sample and sorts ions based on their charge-to-mass ratio. Since seized "bath salts" samples can contain adulterants other than synthetic cathinones, MS would be the best analytical technique to use on these samples because it can separate out the different compounds in a complex mixture and give information on the derivative makeup.

While MS would be the best analytical technique to use for the analysis of synthetic cathinone samples, this technique does have its own limitations. Analysis of a chemical sample with a mass spectrometer usually takes place in a laboratory because these instruments are not mobile due to the dependency of heavy magnets, electronics, and vacuum systems within the instrument by a stable, large power supply.[17] Due to these extensive needs, evidence samples are constantly being collected in the field and transported back to the forensic laboratory for analysis. The ability to have a portable mass spectrometer would allow for samples to be tested in the field if transportation to a laboratory is unfeasible and would allow for more confident identification of suspected illegal substances.

However, when developing a mass spectrometer to use in the field, the portable version must be comparable to its benchtop version. Improving the field portability of MS would revolutionize analysis applications if the portable counterparts would give reliable results through high resolutions of the spectra and have minimal weight.[18] Another problem with creating a portable mass spectrometer is being able to simplify the analysis process for non-technical operators to use for efficiency at the crime scene.[19] Therefore, the problems must be addressed before MS can be used as a portable analytical technique.

First, a portable mass spectrometer needs to maintain the same accuracy and reproducibility as its laboratory counterpart. In MS, this accuracy and reproducibility comes from maintaining a high resolution, meaning that two peaks given by the detector signals are spaced enough part, so they are not misread as a single peak.[20] To produce a high-resolution spectrum, mass spectrometers have a high dependence on the pressure produced by the vacuum in the machine for ions to flow to the detector.[18] Due to this dependency on having a high vacuum for a high resolution, these high-pressure pumps have been miniaturized to maintain the portability of a mass spectrometer for field use.[21] By not losing any resolution by a decrease in vacuum pressure, portable mass spectrometers can analyze a sample without the loss of accuracy and reproducibility when compared to their laboratory counterparts.[19] Considering that the developed portable mass spectrometers have been able to maintain a high vacuum pressure for a high ion pumping

speed, forensic scientists can be confident in the ability of a portable mass spectrometer to give an accurate identification of synthetic cathinones in the field to be taken to the laboratory for further testing.

For MS to be used in the field, the dimensions and weight of the instrument need to be kept at a minimum. In the early days of portable mass spectrometers, the military utilized this technique for on-site explosive residue analysis, but the instrument was mounted in a vehicle due to its size and weight.[21] However, in an effort to make MS apt for remote field testing where vehicles cannot reach, mass spectrometers have been reduced in size for a person to carry. For example, portable mass spectrometers are now being developed to weigh under 15 kilograms and these instruments can either be handheld or be worn like a backpack.[16] By reducing the size of a mass spectrometer to a handheld or backpack version, this analytical technique becomes portable.

Additionally, to aid in crime scene processing efficiency, the analysis of synthetic cathinones with portable mass spectrometers should be able to be done by non-technical operators, such as law enforcement officials or crime scene technicians. With using MS on unknown substances, chemical identification can be almost impossible due to some chemical structures not having a signature peak in the spectrum or variability in the peak intensities.[22] In the case of synthetic cathinones, these compounds share roughly the same signature peak in the spectrum, making identification between derivatives difficult. Therefore, to aid in the identification process, an automated probability matching of samples through software to a standard spectrum found in a reference library would streamline the forensic analysis process for non-technical operators.[19] This software operates on an algorithm that matches the spectra based on precursor ion, product ion transitions, and fragment ions and then designates a probability of the evidence sample and reference compositions matching.[19] As an illustration of its implementation, use of a mass spectra reference library was successful for identification of different synthetic cathinones.[14] With use of a mass spectra reference library matching program, non-technical operators would be able to analyze and identify synthetic cathinone samples on-site. The ability of having non-technical operators quickly identify synthetic cathinones using these library search algorithms would also enhance the processing of a crime scene by law enforcement and crime scene technicians.

Hence, MS is best analytical technique for determining synthetic cathinones in seized "bath salts" evidence samples. This method allows for the accurate and reproducible identification of synthetic cathinone derivatives because MS is specific enough to give detailed results about the chemical composition of a sample. In other words, the small structural differences between derivatives will be clearly shown during analysis. Additionally, this technique is applicable to the on-site analysis of synthetic cathinones. Due to the recent modifications MS has experienced to make these instruments portable, synthetic cathinones are able to be identified in the field with the same confidence as using MS in a laboratory setting. However, an evidence sample cannot be directly analyzed with MS because the sample needs to be broken down into key ions before accelerating to the mass analyzer and detector for the charge-to-mass spectrum to be computed. Therefore, finding an appropriate ion separation method is also a necessity to testing for synthetic cathinones in the field.

4. Gas Chromatography-Mass Spectrometry

One of the most common ion separation techniques paired with MS is the method known as gas chromatography (GC). Through this method, the apparatus separates a complex mixture into different analyte species for a mass spectrometer to detect and analyze. Due to this combination of analytical methods, GC-MS can provide both qualitative and quantitative screening for unknown samples, giving scientists the ability to know what and how much is present. For forensic analysis applications, gaining both qualitative and quantitative information of samples provides definitive and defensible results.[8] Due to this reason, GC-MS is commonly referred to as the "gold-standard" of analytical techniques a forensic scientist can perform. While this method may be referred to as the "gold-standard" for forensic chemical analysis, it may be a contributor to the backlog of processing of suspected synthetic cathinone evidence samples.

GC separation is the most often used analytical technique in forensic science because of its ability to separate any intricate sample. This method is able to separate the components of a complex mixture into different species due to a version of the sample being injected into a heated port, which evaporates the sample, which moves through a heated column oven with the help of a carrier gas; then the separated analytes move to the mass spectrometer. While this technique may seem simple, two things should be taken into consideration—sample preparation and column selection—for successful separation of a complex sample.[20] Considering the criteria for a successful separation, a forensic chemist should be able to effectively analyze synthetic cathinones because these factors have not been a problem for other controlled substances, such as amphetamines. However, three main problems that arise when using GC-MS on synthetic cathinone samples are the extensive sample preparation, the stationary phase used, and thermal

degradation at the injection port.

First, the sample preparation of a seized "bath salts" sample is time-consuming. The solid evidence sample cannot directly undergo GC separation; instead, it has to be transformed into a gas or liquid state for injection into the GC port. For synthetic cathinone separation with GC, an acid/base combined extraction is necessary for sample preparation because the street versions of these samples can contain other adulterants, such as benzocaine and caffeine, or multiple synthetic cathinone derivatives.[23] From the number of steps needed for sample preparation, the sample preparation method is time-consuming. Hence, the sample preparation required to transform the original evidence sample into one that can be injected into the GC port can contribute to the backlog in forensic laboratories because of the extensive process.

Another problem that arises with GC separation of synthetic cathinones is due to the stationary phase used. A complex sample separates into different species due to the affinities different species have to the stationary phase, which coats the inside of the GC column. When selecting a stationary phase column, the chemical properties of the stationary phase, such as polarity and chirality, should match the sample's composition. In forensic laboratories, the most common columns are phenyl columns that are slightly polar to match the common controlled substances being analyzed.[24] However, the influx of synthetic cathinones show that the variety of stationary phases are ineffective for the separation of this class of compounds. Since these compounds exist in different forms, such as enantiomers and structural isomers, a chiral stationary phase should be used. Researchers have found that a polysiloxane-anchored cyclodextrin derivative is the best stationary phase for GC separation of enantiomers and isomers of different organic compounds.[25] When looking at the chirality of synthetic cathinones, this type of column would have the most effective separation both in terms of reproducibility and efficiency.[15] With an efficient stationary phase, the time taken to separate a suspected sample of synthetic cathinones could be significantly reduced due to enhanced separation of the components of the evidence sample.

The last problem associated with GC separation of synthetic cathinones is the thermal degradation of the sample. Synthetic cathinones are unstable at high temperatures, so when the prepared sample is injected into the heated port, the compound degrades.[13] The main reason for fragmentation in the mass spectrum of synthetic cathinones is due to thermal degradation at the GC injection ports.[14] Due to the fragmentation, the mass spectrum of a sample shows weak or even absent peaks, which impedes the ability to distinguish between synthetic cathinone derivatives.[9] To avoid thermal degradation, the incorporation of a resistive heating system, as seen in low thermal mass (LTM) GC, around the GC column can allow for temperature to be controlled, ultimately enhancing the mass spectrum.[7] While resistive heating methods can be incorporated into the design of the GC column, forensic laboratories do not have the ability to actually include these methods in their instrumentation. Therefore, thermal degradation of the suspected synthetic cathinone sample still occurs, causing inaccurate identifications.

The current "gold-standard" of analytical techniques on synthetic cathinone samples is ineffective due to the extensive sample preparation, lack of use on the proper stationary column, and thermal degradation of the sample at the injection port. While the latter two problems could be fixed with use of a polysiloxane-anchored cyclodextrin derivative column and integration of a resistive heating system around the column, forensic laboratories cannot afford this solution due to the existing administrative issues. Thus, suspected synthetic cathinone samples will continue to have the mass spectral fragmentation, leading to misidentification of the molecule. Even if money was spent on buying a portable GC-MS system and including these solutions for synthetic cathinone analysis, the time-consuming sample preparation causes this method to be impractical for field use. On-site identification of suspected synthetic cathinones samples by MS must have a better key ion identification.

5. Ambient Ionization-Mass Spectrometry

In a recent effort to create a portable method of extracting key ions necessary for the creation of a unique mass spectrum for a compound, analytical chemists developed a new technique called ambient ionization. Normally, separation of complex mixture occurs through a chromatographic method, such as GC, before the separated species enter into the mass spectrometer for ionization and creation of the charge-to-mass spectrum. However, ambient ionization allows for these key ions to already be extracted from a sample outside of the mass spectrometer.[26] By having ionization occur under ambient conditions, these techniques can help forensic laboratories by allowing trace-level analysis, requiring minimum sample preparation, and screening samples quickly.[19] These advantages over GC show that ambient ionization should be explored as a forensic technique for the on-site analysis of synthetic cathinones. While a variety of ambient ionization methods have been developed in the past couple years, two techniques, desorption electrospray ionization (DESI) and direct analysis in real time (DART), have become the most

prominent in forensic applications.

5.1. DESI-MS

One of the first MS techniques coupled with ambient ionization was DESI-MS. This method aims an electrospray of charged species and ions at a surface for analysis, which hits the sample surface directly, ionizes the molecules, and delivers them into the mass spectrometer inlet port.[27] According to the pictorial representation, a high-pressure gas assists the electrospray droplets in colliding with the sample in such a way for new progeny droplets to be ejected from the sample at various sizes, speeds, and angles towards the mass spectrometer inlet.[26] To determine if this method is appropriate for on-site analysis of synthetic cathinones, the instrumentation and sample preparation must be minimal while creating strong mass spectral signals in a complex matrix.

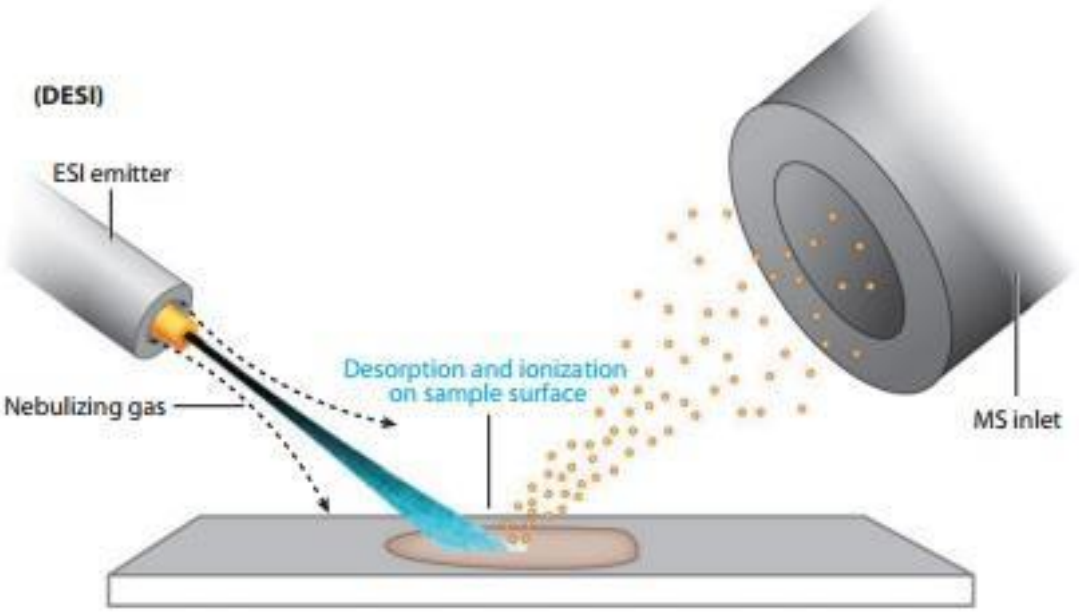

Figure 2: Schematic representation of DESI-MS on a sample.[26]

The instrumentation, sample preparation, and analysis process for DESI-MS is a quick and simple process for the on-site analysis of synthetic cathinones. A syringe pump containing the DESI solvent, another pump containing the DESI nebulizing gas, and a portable mass spectrometer are the only items needed.[28] Considering the simplicity of these pumps, a forensic chemist could fabricate the pumping instrumentation needed for DESI using supplies found at the hardware store to best match their needs for portability. As for the sample preparation, because this method is able to analyze samples in the solid state, the only necessary sample preparation is placing a small amount of the powder sample on a well slide for testing.[19] The minimal amount of sample preparation shows that this process would be appropriate for field use when compared to the extensive process required for GC. With DESI-MS, an illicit drug sample analysis took approximately 35 seconds because of the minimal sample preparation involved.[28] The quickness of the analysis process shows that this technique can be used effectively in the field. Since the overall process of creating the instrumentation necessary and preparing the sample for DESI-MS analysis is straightforward, this technique could be used as a portable forensic method. Additionally, with a portable mass spectrometer that is combined to a mass spectral library search algorithm, DESI-MS can be performed by non-technical operators, such as law enforcement officials and crime scene technicians, saving forensic laboratory resources.

For this technique to be implemented for portable analysis of synthetic cathinones, it also needs to be able to show success on distinguishing between derivatives in this illicit drug class and other drugs when compared to the current method of GC-MS. DESI-MS is able to accurately identify different synthetic cathinone varieties by their precursor ions because it does not experience in-source fragmentation due to sample degradation.[28] When comparing DESI-MS to the currently used method of GC-MS, the lack of in-source fragmentation of the sample means that the mass

spectrum of synthetic cathinones does not experience the weak or absent peaks seen in GC-MS, allowing for accurate identification between derivatives and controlled substances with similar structures like amphetamines. Additionally, seized "bath salts" samples are rarely just one synthetic cathinone derivatives; instead, they can contain multiple derivatives, other drugs, or adulterants. The combination of compounds in this complex matrix muddles the mass spectrum when using GC-MS, making proper identification of the sample even harder. However, the ability of DESI-MS to give intense spectral signals allow for forensic chemists to distinguish between derivatives and other drugs.[28] Since DESI-MS has been shown to correctly classify multiple derivatives of synthetic cathinones among other adulterants in a sample, this technique could be used either in the laboratory or on-site as a rapid analysis technique to identify suspected illegal substances, like synthetic cathinones.

5.2. DART-MS

Another renowned ambient ionization method is DART-MS. As the pictorial representation shows, a DART ion source creates excited gaseous atoms, which are pointed at the sample in open air and ionize it.[29] By exposing the sample to a constant stream of an electronically excited gas species, commonly helium, the sample ionizes due to the energy transfer between the gas species and the sample under the Penning mechanism.[26] While this technique has been effectively shown under laboratory conditions to create mass spectra of different compounds, the instrumentation and sample preparation must be minimal while having enhanced mass spectral signals for on-site analysis of synthetic cathinones.

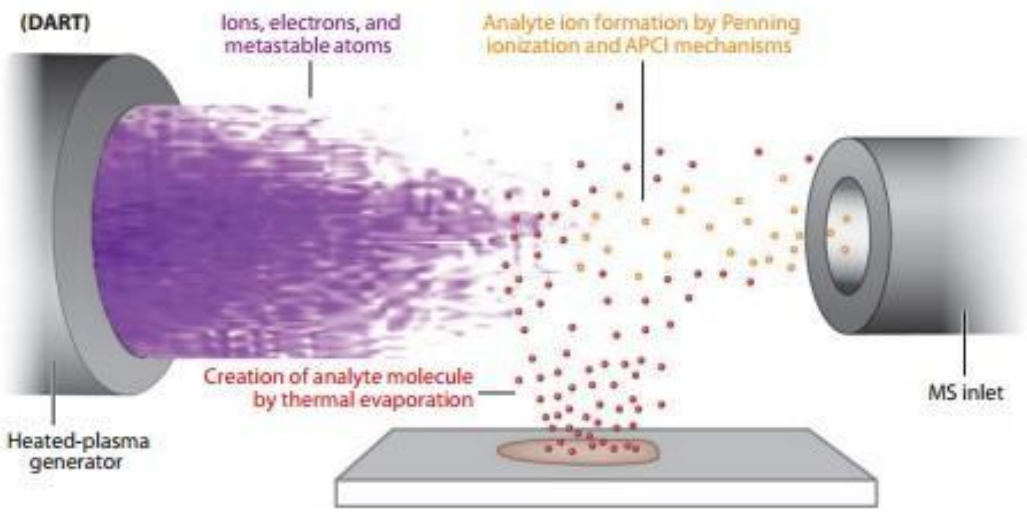

Figure 3: Schematic representation of DART-MS on a sample.[26]

As seen with DESI-MS, the overall instrumentation setup, sample preparation, and analysis process with DART-MS is relatively speedy and effortless. The DART ion source can actually be placed onto the portable mass spectrometer with an approximate 1.5 centimeter gap between the two systems for the sample.[30] While the DART ion source would have to be bought, the ability to attach it directly on the mass spectrometer without the need for extra pumps and solvents improves its portability. As for sample preparation, the closed end of a capillary melting tube can be dipped into the solid sample and held between the DART source and mass spectrometer inlet.[9] Comparing this sample preparation to the numerous steps seen with GC-MS, the ability to directly analyze solid samples simplifies the process for DART-MS to be used in the field. The minimum amount of sample preparation also means that the analysis time is rapid. The mass spectrum only takes a couple seconds to appear on the computer screen once the sample is placed between the DART ion source and the mass spectrometer inlet.[31] With the seconds that it takes for the mass spectrum to appear on the screen, the method becomes one that can be used on-site because a forensic chemist can conduct multiple analyses within a small amount of time. Hence, the rapidness of instrumentation setup, sample preparation, and analysis process allows for this method to be a portable one, especially when compared to the current method of GC-MS.

While this method has the capability to be portable, DART-MS also has to be able to accurately identify synthetic cathinones for it to be used for on-site analysis of synthetic cathinones. Using DART-MS on synthetic cathinone samples in the laboratory, the occurrence of the molecular ion peak, a critical aspect of identification of synthetic cathinone derivatives, was able to be seen clearly due to the soft ionization conditions preventing in-source fragmentation.[9] The prevention against in-source fragmentation allows for the small difference between synthetic cathinone derivatives to be enhanced on the mass spectra of these compounds. In addition, considering the fact that evidence samples seized by law enforcement officials typically contain more than one cathinone derivative and other adulterants, DART-MS was able to show molecular ion and key product ion peaks of each compound in the mixture for accurate identification.[9] Since DART-MS can be used to analyze a complex mixture and still accurately identify synthetic cathinones, this technique can also be used as a portable technique for the on-site analysis of suspected samples. Therefore, forensic scientists or even non-technical operators, with use of a mass spectral library search algorithm, can accurately identify suspected synthetic cathinone samples in the field with the use of DART-MS, so those samples can be sent to a laboratory for further analysis.

6. Conclusion

With the recent rise of the synthetic, illicit drug market, forensic laboratories have experienced an evidence backlog, causing long turnaround times on controlled substance analyses. The forensic laboratory backlog can be attributed to two problems: administrative and emerging drugs. Forensic laboratories do not have the resources available to invest in hiring new scientists to keep up with the increase in workload. Additionally, forensic chemists cannot keep up with the rise of cathinone derivatives, commonly referred to as "bath salts," because these emerging synthetic drugs have similar analysis responses. The derivatives in this drug class create similar analysis responses due to the closeness in their chemical structures, isomerism, and chirality. However, this issue of backlogs on synthetic cathinone evidence samples could be solved through the use of a portable analytical technique that even non-technical operators, such as law enforcement officials and crime scene technicians, could perform to identify suspected samples before laboratory analysis confirms the results.

When considering analytical methods, MS is the best for determining the chemical structure of a suspected synthetic cathinone sample because of its broad applicability and sensitivity. With the ability to maintain high vacuum and low weight for portability along with the addition of a mass spectral library search algorithm for accurate identification of compounds, MS shows the best ability for analyzing synthetic cathinones in the field by either forensic chemists or non-technical operators. While this technique is the best for on-site testing of synthetic cathinones, a portable ion separation method needs to be chosen to separate the complex sample for MS analysis.

For separation of complex samples, GC is most commonly used in forensic laboratories. However, this technique is not the best for the separation of synthetic cathinones because of the extensive sample preparation, lack of appropriate stationary phase used, and thermal degradation of the sample at the heated injection port. Through use of a polysiloxane-anchored cyclodextrin derivative stationary phase and resistive heating systems around the column, GC-MS could effectively separate synthetic cathinones. However, after spending the resources on a portable GC-MS system and incorporating these solutions for synthetic cathinone analysis, the extensive sample preparation and amount of time needed for analysis would still make this method impractical for field use.

Therefore, ambient ionization is a better separation and extraction technique to be coupled with MS for the on-site forensic analysis of synthetic cathinones because of portability and accuracy. The two main ambient ionization techniques coupled with MS are DESI-MS and DART-MS. First, both of these methods require little to no sample preparation. When compared to the length of time needed to prepare a synthetic cathinone sample for GC-MS, the minimal amount of sample preparation allows for direct analysis of a sample within a matter of seconds. Additionally, these techniques can show the enhanced mass spectral peaks for synthetic cathinones when in complex mixtures of other derivatives, drugs, and adulterants. The enhancement of the mass spectra is another gained advantage over GC-MS because ambient ionization does not cause in-source fragmentation of the sample. The lack of fragmentation allows for these compounds to be accurately identified by a chemist or mass spectral library search algorithm. Ultimately, the use of one of these ambient ionization techniques coupled with MS would reduce the forensic laboratory backlog because the techniques will allow for presumptive testing of potentially illegal substances, such as synthetic cathinones, which will reduce the number of samples sent in to the laboratory.

7. Acknowledgements

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