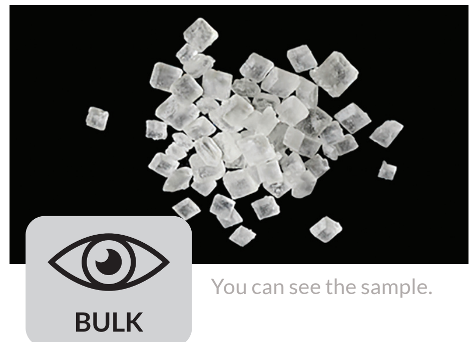
WHITE PAPER:

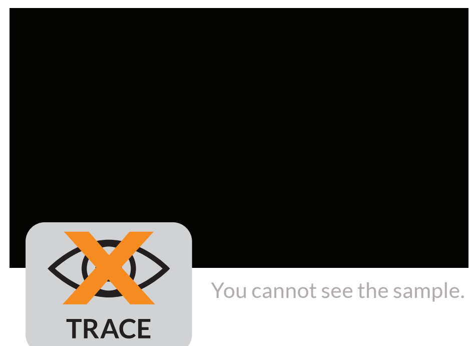
A New Approach to Trace Detection

Introduction

When most people think of "trace detection" they likely consider being pulled aside at airport security to have their belongings randomly swabbed for explosive residues. While this is true, trace detection of highly toxic materials in the field by emergency responders needs further clarification in light of the opioid epidemic plaguing our communities and the emerging threat of fourth generation chemical warfare agents (a.k.a. FGAs or "Novichoks"). There are two definitions of "trace" which need to be considered in this context. The first, which comes from the explosives detection world, is the "invisible" which is the presence of a threat material unseen by the naked eye. Generally, this refers to less than one microgram of total product. Examples include contaminated surfaces at clandestine labs, emptied containers from trash pulls, and surfaces in public places following a chemical warfare agent (CWA) release. The second, which comes from the narcotics world, is the "hidden" which is the presence of a small (yet potentially lethal) percentage of a threat material within a bulk (visible) amount of something less harmful. Examples include synthetic opioids heavily diluted with cutting agents for personal consumption and controlled substances dissolved in solvents to evade field detection at checkpoints. Today's emergency responders and security personnel need detection capabilities which address both categories with high sensitivity (the ability to detect threat materials below harmful levels) and high fidelity (the ability to detect reproducibly and reliably).



You can see the sample.



You cannot see the sample.

With MX908 in their toolkit, emergency responders can face emerging threats with confidence.

Trace Detection Challenges

To date, field trace detection has been limited to either ion mobility spectrometry (IMS), gas chromatography mass spectrometry (GCMS), colorimetric assays or canines, depending on the specific application. While partially effective, each of these approaches has limitations in its ability to evolve with the emerging threat landscape. Though highly sensitive, IMS lacks selectivity or the ability to differentiate like materials, so detectors based on this technology normally have libraries of less than a dozen or so compounds. Consequently, they tend to produce relatively high rates of false positives. Furthermore, IMS systems are often prone to overloading which results in significant downtime. GCMS systems, on the other hand, are highly selective and sensitive, but require expert operators, have burdensome logistics trails, are heavy (30 lbs. / 14 kg) and expensive to obtain (~ $100,000 USD), and require lengthy warm up periods and tens of minutes for analysis. Colorimetric assays require user interpretation and are often plagued with false responses due to cross reactivities. While they generally have difficulty with very low concentrations, they can be useful for certain "hidden" samples. Additionally, canines are trained to detect a very specific set of threats and require the use of highly trained handlers. Due to their lack of selectivity, canine workloads are limited. To provide the required sensitivity, breadth of capability, operational readiness, and low logistical burden, a new approach to trace detection is needed.

When compared to other tools, MX908 provides comparable sensitivity with much higher fidelity.

Bulk Detection Challenges

Since the mid-2000s, first responders have also been fielding optical detection technologies based on infrared (FT-IR) and Raman spectroscopy. These devices provide extremely high fidelity owing to their molecular specificity but are limited to detecting and identifying bulk (visible) amounts of material. Indeed, optical tools typically cannot detect materials at less than 10% of a mixture. When fentanyl is prepared for street consumption, it must be heavily diluted to prevent an overdose since its analgesic dose is so small (2.5 micrograms). A typical street sample of fentanyl contains about 1 – 3% of the opioid, which is well below the typical optical detection threshold. A suspected drug powder identified as lactose or heroin by FT-IR or Raman could create a false sense of security for the responder because the trace amount of fentanyl hidden inside could be hazardous if not handled properly. To address this concern, bulk detection must be paired with reliable trace detection capability.

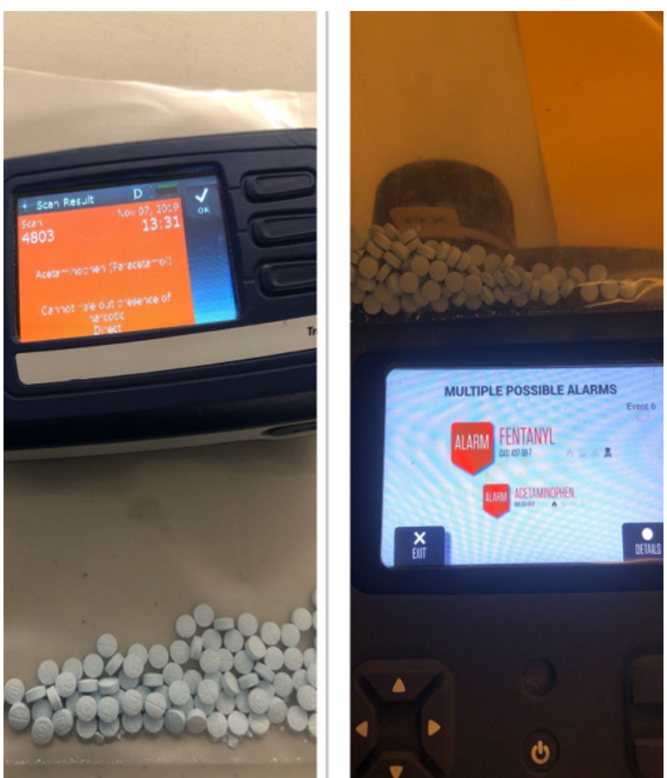
Bridging the Detection Capability Gap

Compared to trace detection technologies, high pressure mass spectrometry (HPMS) affords comparable sensitivity with much higher fidelity. For reference, the detection limit of HPMS for synthetic opioids is less than 100 nanograms (20 ng for fentanyl), which is up to 1000X less than the analgesic dose of fentanyl (25 - 125 micrograms). HPMS as deployed in the MX908 was engineered to minimize sample overloading and carryover by isolating the sampling region (where thermal desorption occurs) from the analysis region (the mass spectrometer). However, the most unique aspect of HPMS compared to other trace techniques is that it produces a mass spectral image. This image represents the mass pattern of the detected substance, which is

Detection Approach	Sensitive	Selective	Threat Coverage	Easy to Use	False Positive Rate	Detection Speed
HPMS	Yes	Yes	Broad	Yes	Minimal	Fast
IMS	Yes	No	Limited	Yes	High	Fast
GCMS	Yes	Yes	Broad	No	Low	Slow
Colorimetric	No	Yes	Limited	No	High	Fast
Canine	Yes	No	Limited	No	Minimal	Fast

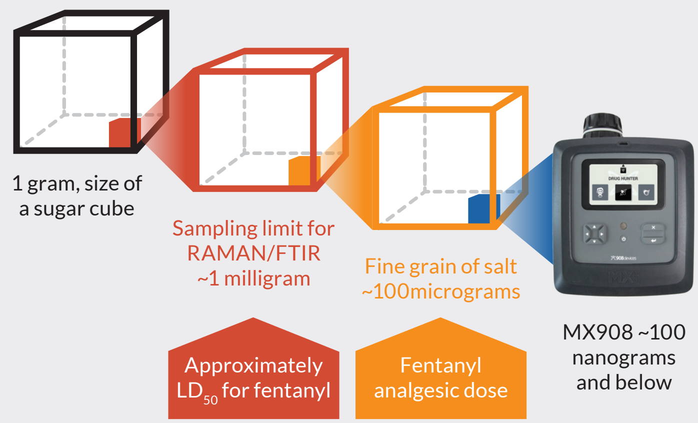
a fundamental chemical property, and which can be reviewed and interpreted post-event. Such is not the case for IMS data, color changes, or canine behavior.

Compared to bulk detection technologies, HPMS can detect threat materials at very low percentages in complex mixtures and has demonstrated the ability to detect below 1% by volume in a mixture depending on the cutting agent. This is because HPMS is particularly sensitive to drugs such as synthetic opioids, and its thermal desorption process and detection algorithms tend to provide immunity to benign cutting agents. That being noted, using HPMS with a bulk detector provides valuable information to the responder. For instance, if a bulk detector reports lactose and HPMS reports fentanyl for a suspect powder, that product is heavily cut and presents less danger than a powder for which both detectors report fentanyl and is therefore more concentrated.



Example of trace analysis with MX908. The device identified fentanyl in addition to confirming the acetaminophen found when using Raman spectroscopy.

Trace Analysis

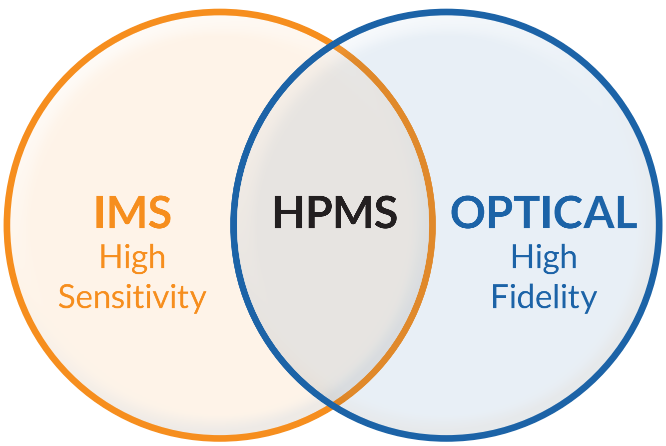


Two Ways of Considering Trace Levels of Fentanyl Analysis

	Invisible	Hidden
Trace Sample Type	The human eye can see about 50 microns (1/2 a human hair)	A "knot" or "stamp" bag of street fentanyl contains about 1 gram of powder
Typical Sample Quantity	A typical fentanyl particle is 2 microns which is 25X smaller than what the eye can see and equates to a mass of 4,400 ng	A typical street cut contains about 3% fentanyl by mass = 30 milligrams (12X LD_{50})
Detection Challenges	Low Absolute (ng) LODs Required	Low relative LODs (less than 5% in mixture) required
MX908 Capability	With a fentanyl LOD of 20 ng, the MX908 is 1000X more sensitive than its analgesic dose (as low as 25 nanograms), meaning the opioid can be detected well below harmful levels	MX908 can detect fentanyl as low as 0.1% in a mixture which is 30X more sensitive than a typical cut amount and 100X more sensitive (on a % basis) than bulk techniques

The Power of HPMS

To produce a mass spectral image, HPMS ionizes the chemical material and fragments it into characteristic smaller masses. The images produced for controlled substances and FGAs by the MX908 HPMS engine are further enhanced through a process called Collision Induced Dissociation (CID). Essentially, CID breaks materials into extremely specific mass patterns using a sequence of increasingly higher energies during the ionization process to maximize detection fidelity. HPMS is also unique because it is not limited to its library to detect novel chemical threats. In addition to being able to identify hundreds of threat materials by name and Chemical Abstract Service (CAS) number, the MX908 can alert to > 2,000 novel fentanyl analogs using a predictive algorithm based on the mass spectral image it detects. This predictive approach is difficult for other technologies because the data they produce are either not inherent to chemical structure (in the case of IMS) or are influenced by chemical interactions such that the resulting spectra cannot be known with any certainty until they are directly measured (in the case of FTIR and Raman).



Summary

MX908 provides the best of both worlds for field trace detection. It has the sensitivity of other trace methods to detect those “invisible” threats combined with a specificity comparable to bulk methods to detect those “hidden” dangers. With MX908 as part of a detection toolkit, emergency responders and security personnel can face the emerging threat landscape with confidence.

Learn more about MX908 at **908devices.com/MX908**

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