NIJ National Institute of Justice

Technology Transition Workshop| *José R. Almirall, Ph.D.*

# *Introduction to Drugs and Explosives Detection*

# *Outline*

- **Existing technologies for detection**
- **Detection of illicit substances in the form of particle residues or “trace”**
- **Detection of illicit substances in the form of “vapors”**
- **Biological detectors**
- **Instrumental detectors**
- **Conclusions**

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# *Motivation for This Work – Provide Additional Tools for Detection …*

## Worldwide Explosive Attacks

| Year | Location | Type | # of Deaths |
|---|---|---|---|
| 2009 | Peshawar, Pakistan | Suicide car | ~100 |
| 2008 | Mumbai, India | Car, Buildings | 175 |
| 2005 | London, UK | Suicide | ~50 |
| 2000 | Aden, Yemen | Suicide boat | 19 |
| 1998 | Kenya & Tanzania | Truck | 223 |
| 1995 | Oklahoma City | Truck | 168 |

## Illicit Drugs, US Statistics in 2003

| | Methamphetamine | Cocaine | Heroin | Marijuana |
|---|---|---|---|---|
| Consumed | 21.7 tons | 285 tons | 19.8 tons | N/A |
| Seized by FA | 3.71 tons | 115.72 tons | 2.35 tons | 1224.2 tons |

Data from Drug Identification Bible® 2004/2005 Edition (2004)

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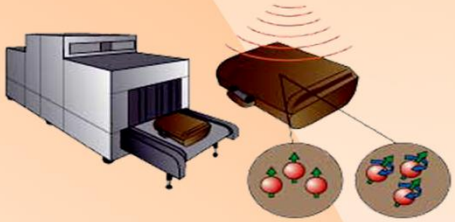
# Chemistry and Detection of Explosives

**Types of Explosives & Characteristics of Explosives** → **Low Explosives & <u>High Explosives</u>** → **Commercial & <u>Military</u>** → **Plastic Explosives (C4, Semtex & Detasheet)**



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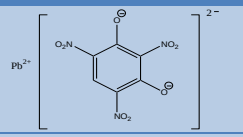
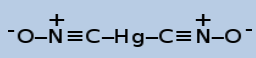
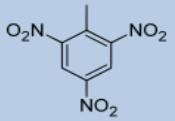
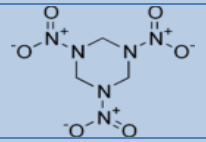
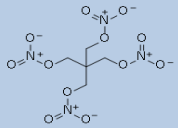
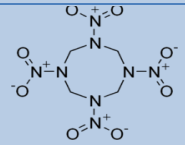
# Explosives

Types of Explosives & Characteristics of Explosives → Low Explosives & High Explosives → Commercial & Military → Plastic Explosives (C4, Semtex & Detasheet)

## Low explosives deflagrate (< 1000 m·sec$^{-1}$)

| Low explosives | Chemical Structures |
|---|---|
| Black powder | Sulfur<br>Charcoal<br>Potassium nitrate |
| Black powder substitute | Black powder+<br>Graphite/Potassium perchlorate, etc. |
| Smokeless powder | Nitrocellulose<br>Nitroglycerin<br>Nitrocellulose |

## High explosives detonate (1000 to 3000 m·sec$^{-1}$)

| High explosives | Chemical Structures | |
|---|---|---|
| Lead styphnate |  | Primary |
| Mercury fulminate |  | Primary |
| TNT |  | Secondary |
| RDX |  | Secondary |
| PETN |  | Secondary |
| HMX |  | Secondary |
| ANFO | $NH_4NO_3$<br>$C_nH_{2n+2}$ | Secondary |

## Commercial explosives:

Nitroglycerine
Ammonium nitrate
Ammonium nitrate fuel oil

→ Dynamite
→ Slurry explosives
→ Emulsion explosives

## Military explosives:

Black, smokeless powder
Picric acid
TNT, PETN, RDX, HMX
Mixtures: C-4, Torpex 2

→ Shelling filling
→ Blasting caps
→ Bursting charges
→ Demolition charges

Beveridge (1998)

# *Detection Technologies*

**Bulk systems: Detect the main mass of explosives hidden inside concealing containers .**

X-ray

Neutron activation

Millimeter wave

**Trace systems: Detect small quantities of explosives that are present on or above the surface of containers due to contamination or vapors penetrating from the bulk explosives.**

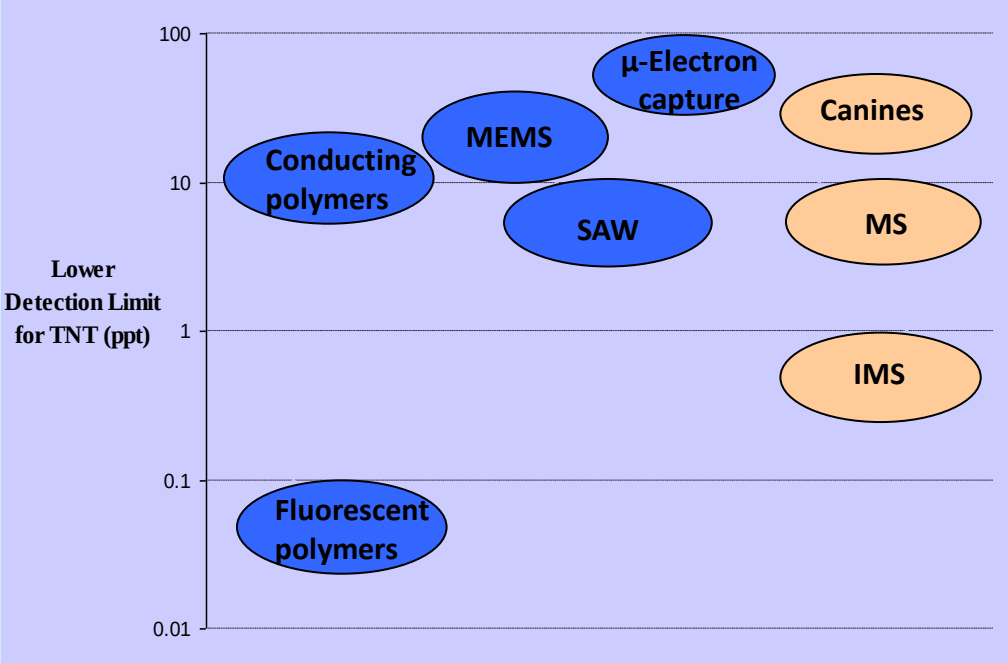
GC CE MS

Laboratory detectors

Canine IMS MS

Field detectors

# Detection Technologies (Continued)




**Trace systems:** Detect small quantities of explosives that are present on or above the surface of containers due to contamination or vapors penetrating from the bulk explosives.



GC CE MS

Laboratory detectors



Canine IMS MS

Field detectors

# *Detection Technologies (Continued)*

## Effects of Properties of Explosives on Detection

1) Electronegativity
2) Adsorbtivity
3) Thermal stability
4) Frangibility
5) **Vapor pressure**

**Current E-noses are not effective to detect explosives whose vapor pressure is very low, such as RDX, and PETN in plastic explosives.**

**United Nations Office on Drugs and Crime – Convention on the Marking of Plastic Explosives for the Purpose of Identification (1991)** https://www.unodc.org/tldb/en/1991_Convention_Plastic%20Explosives.html

**Plastic explosives:**

| Component | Composition C-4 | Detasheet | Semtex A/H |
|---|---|---|---|
| **Main explosive** | RDX | PETN | PETN / PETN & RDX |
| **Plasticizer** | dioctyl sebacate, diotyl adipate | | di-n-octyl phthalate, tri-n-butyl citrate |
| **Binder** | polyisobutylene | | styrene-butadiene rubber |
| **Other** | motor oil | Plasticizer, binder, nitrocellulose | Antioxidant: N-phenyl-2-naphthylamine<br>Dye: Sudan IV / Sudan I |
| **Taggant** | DMNB | DMNB | EGDN or DMNB |

**SPME-IMS**

**Utilize SPME-IMS for headspace sampling and detection of the non-energetic volatile signature compounds.**

# *ID of Evidence*


**Which method of detection is the best?**

**2-ethyl-1-hexanol**

**RDX**

C4

***Vapor***

**Dog**

**Presumptive ID of odors from within specimen in seconds**

***Particles***

**IMS**


**Presumptive ID of surface particles in seconds/minutes**

***Vapors/ Particles***

**GC/MS**

**Confirmatory ID of surface particles/odors in hrs/days**

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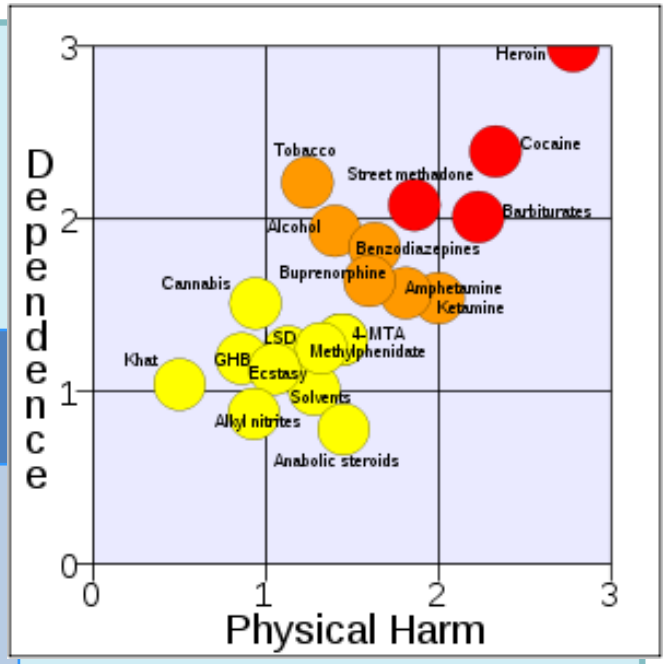
# CHEMISTRY OF DRUGS

**Drugs categories:**
- Stimulants
- Depressants
- Hallucinogens
- Opiates and opioids

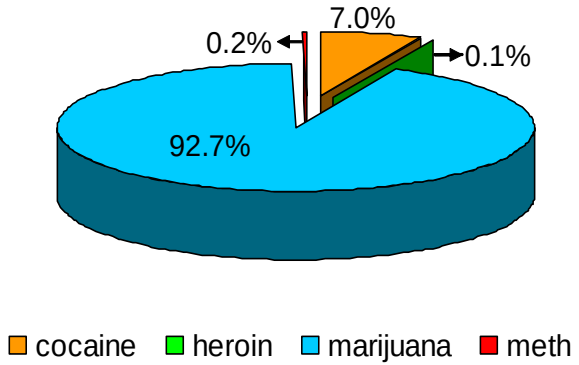
| Schedule | Examples | Potential for Abuse | Accepted Medical Use |
|---|---|---|---|
| I | LSD (Lysergic acid diethylamide)<br>MDMA (3,4-methylenedioxymethylamphetamine<br>Cannabis (marijuana)<br>Heroin<br>Psilocybin | High | Not accepted |
| II | Cocaine<br>Morphine<br>Opium<br>Amphetamine<br>PCP (Phencyclidine) | High | Accepted with restriction |
| III | Lysergic acid<br>Ketamine<br>Synthetic tetrahydrocannabinol (THC) | Less than I and II | Accepted |
| IV | Benzodiazepines | Low | Accepted |
| V | Codeine, low dose | Lowest | Accepted |

Gahlinger (2004)



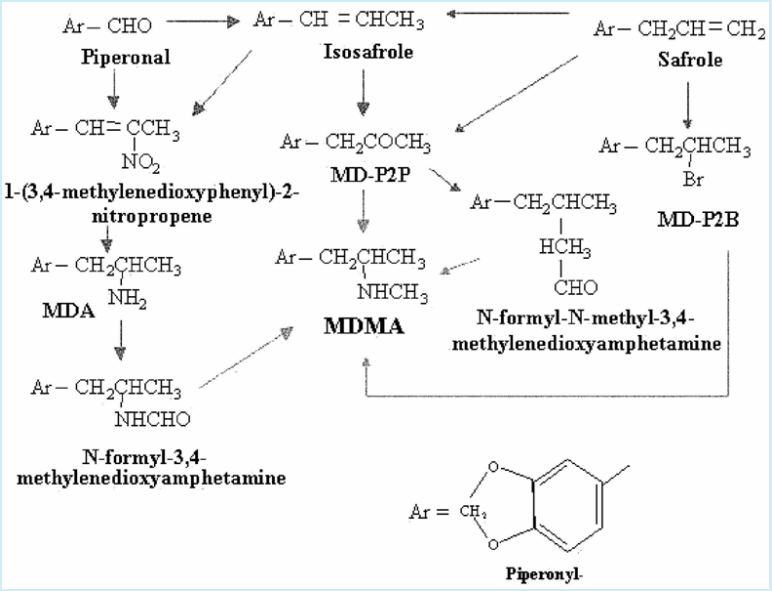

Nutt et al. (2007)

**DEA Drug Seizured in United States 2008**

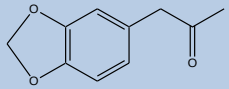
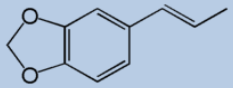
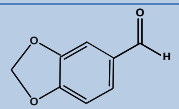
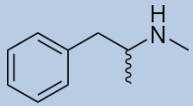


# Volatiles from MDMA

**Each batch has a different impurity profile containing varying amounts of the decomposition products, by-products, and un-reacted precursors.**


Lorenzo et al. (2003)

| Impurities | Chemical Structure | Vapor Pressure |
|---|---|---|
| MDP2P, (3,4-Methylenedioxy) phenyl-2-propanone ) |  | 0.00495 mmHg at 25 °C |
| Isosafrole |  | 0.0929 mmHg at 25 °C |
| Piperonal |  | 1 mmHg at 87 °C |
| Methamphetamine |  | 0.163 mmHg at 25 °C |

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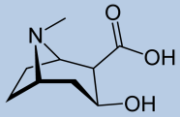
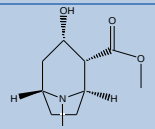
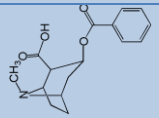
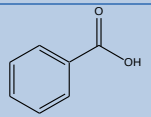
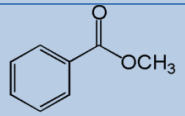
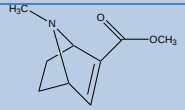
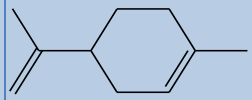
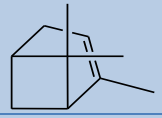
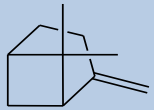
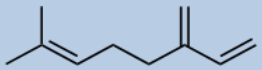
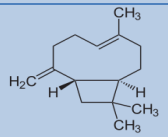
# Volatiles from Cocaine & Marijuana

*Cocaine salt form* *Cocaine free base*

| Impurities | Chemical Structure | Vapor Pressure |
|---|---|---|
| Ecgonine |  | ---- |
| Methyl ecgonine |  | ---- |
| Benzoyl ecgonine |  | ---- |
| Benzoic acid |  | $7.5 \times 10^{-4}$ mmHg at 25 °C |
| Methyl benzoate |  | 0.38 mmHg at 25 °C |
| Ecgonidine methyl ester |  | $0.3 \times 10^{-2}$ mmHg at 20 °C |

*flower* *resin* *hash oil*

| Volatile constituents | Chemical structure | Vapor pressure |
|---|---|---|
| Limonene |  | 1.3 torr at 20 °C |
| α-pinene |  | 3.0 torr at 20 °C |
| β-pinene |  | 2.0 torr at 20 °C |
| β-myrcene |  | 7.0 torr at 20 °C |
| β-caryophyllene |  | N/A |

Dejarme et al. (1997)
Furton et al. (2002)
Lukaszewski and Jeffery (1980)

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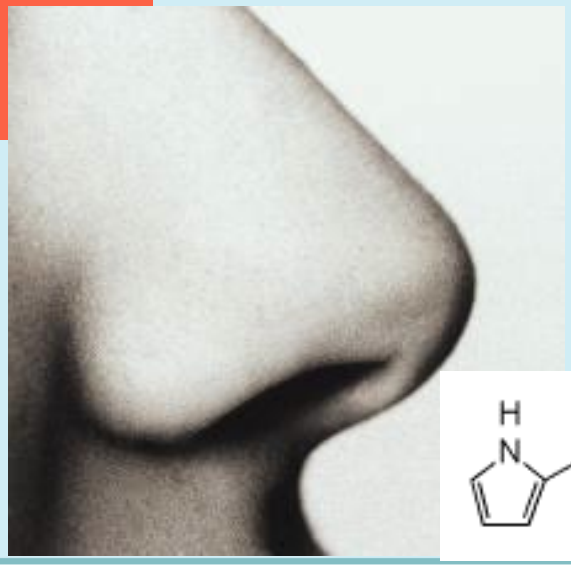
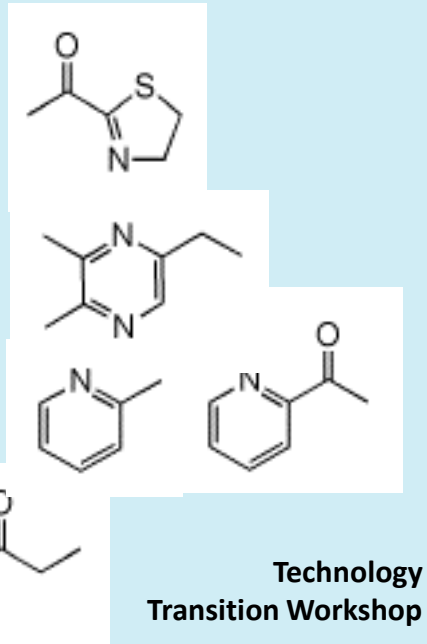
# *Odor Detection – Popcorn (Pv~0)*

**2-acetylpyridine**
**2-methylpyrazine**
**acetylthiazoline**
**ethyldimethylpyrazine**
**propionylpyrrole**





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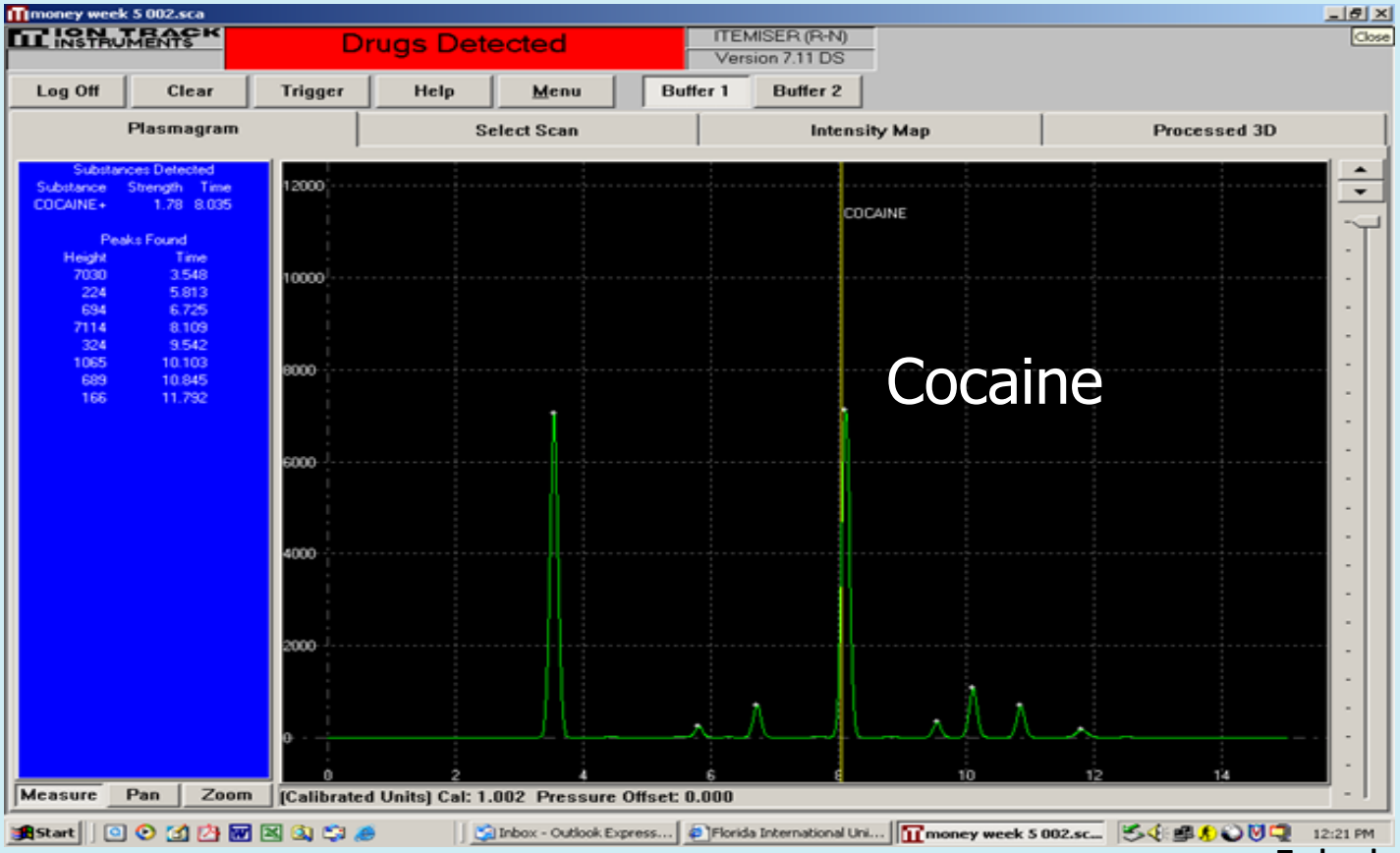
# Currency & Drugs

***An alert (positive) to cocaine on currency by a current IMS has little legal significance since most circulated $ is contaminated with cocaine***

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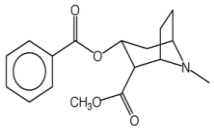
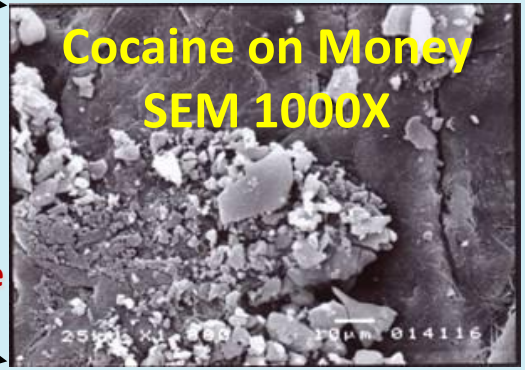
# An alert by a properly trained drug dog indicates that the currency had recently, or just before packaging, been in close proximity to a significant amount of narcotics.

***This is because K9s alert to the odor chemical methyl benzoate which is not found on circulated currency.***

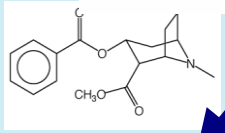
**Circulated Currency**

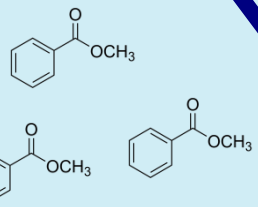
**10 ng surface**





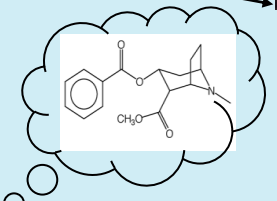

**Dogs are trained on 1 to 1,000+ g cocaine**






**"Crack" Cocaine**

**1ng/sec of methyl benzoate**



**Drug Dog**

Furton et al. (2002)

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# Piperonal (Ecstasy Odor) Detection


Canine Response (%)

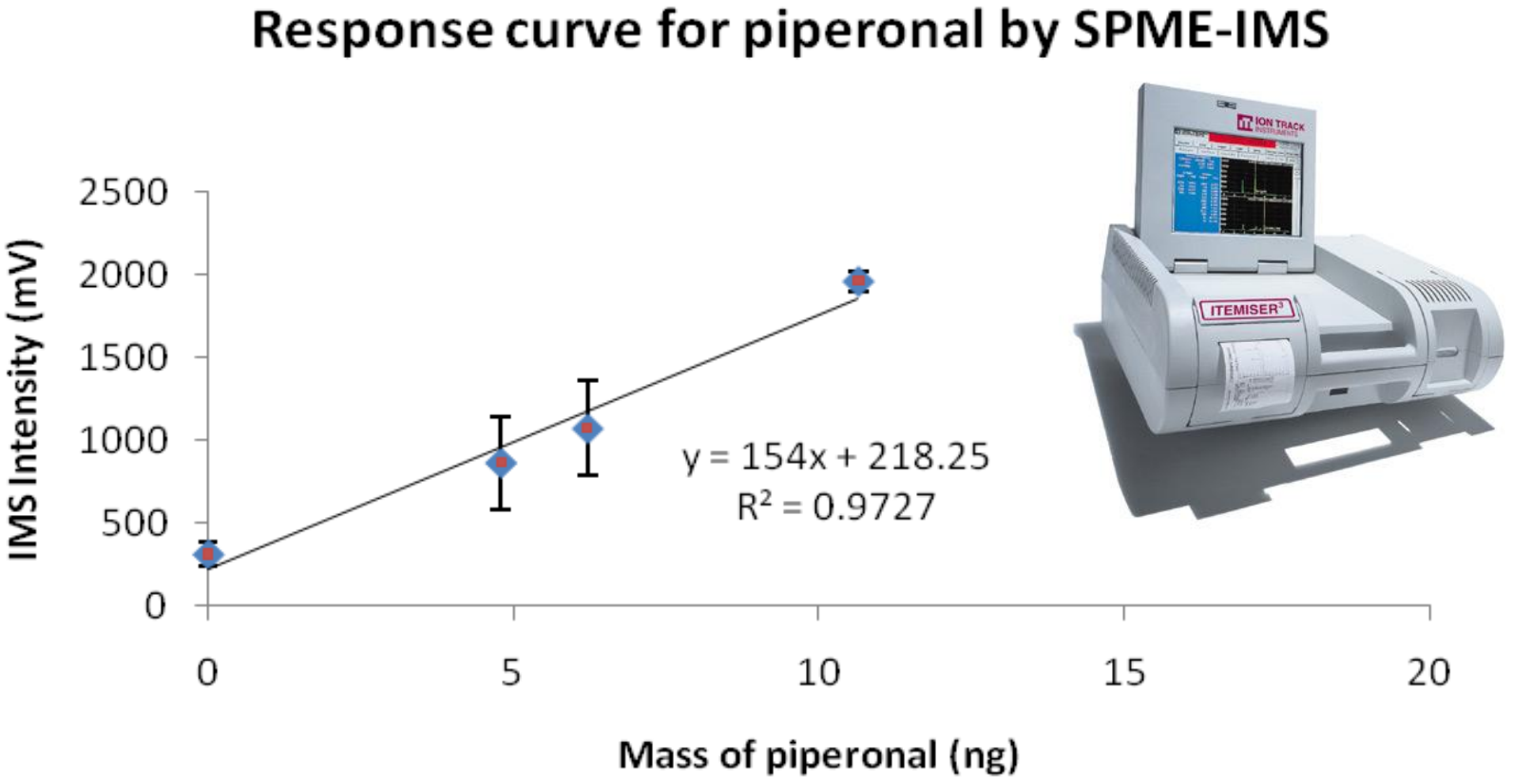
100
90
80
70
60
50
40
30
20
10
0

1
10
100
1000
10000

Permeation Rate (ng s-1)

Macias et al. (2010)

# Piperonal (Ecstasy Odor) Detection (Continued)




Macias et al. (2010)

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# *Presumptive and Confirmatory Tests*

- **Field testing is usually presumptive or screening**
- **Field detection can lead to further investigation and probable cause (this is not a legal opinion) for further search, depending on the situation**
- **Confirmatory tests are conducted in accredited laboratories under more controlled conditions by qualified scientists using standardized and validated scientific methods**
  - **These are the results presented in court**

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# *Conclusions*

- **There are a number of existing technologies for drugs and explosives detection**
- **Trace detectors target contamination from contact**
- **Particles and vapors target different compounds**
- **Biological and instrumental detectors can be used for vapor detection, with canines currently as the state-of-the-art**
- **Instrumental detectors offer some advantages**
- **Confirmation is usually done in lab**

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# *Questions?*

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# *Contact Information*

**Professor José R. Almirall, Ph.D.**

**Department of Chemistry and Biochemistry**

**International Forensic Research Institute**

**Florida International University**

**11200 SW 8th Street, OE116**

**Miami, FL USA**

**305348.3917**

**almirall@fiu.edu**

FIU International Forensic Research Institute

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