Fast carry-on luggage screening method for explosive detection

Gonzalo Fernández de la Mora, César Barrios-Collado, Mario Amo-González

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Outline

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Application: Luggage screener
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1. Introduction

• Company overview
  – Expertise in analytical instrumentation for detection of compounds in trace concentrations (including nanoparticles).
  – Commercialization of Differential Mobility Analyzers (DMA) and Ionization sources.
  – Based on Juan Fernández de la Mora know-how, cofounder and Full Professor at Yale University.
2. Analysis equipment

**Blank Atmospheric Samples**: comprised of 500 L of air sampled in Boecillo at the end of July, when de vapor concentration is maximum according to a previous study.²

**Filters**: Fiber glass/ stainless steel coated with Tenax GR. Allows sampling flow rates in the range of 100 – 1000 L/min.

**Thermal Desorber**: The filter is inserted in the desorber and desorbed at a flow rate of 0.2 L/min and a fixed temperature of 200 °C.

**Cold Trap**: The vapors liberated in the desorber are condensed and retained in a cold trap at 0ºC. The cold trap is built from a silica lined stainless steel tube 1/18”.

**Multicapillary Column GC (MCC-GC)**: 20 cm length, 1000 capillaries in parallel, 40 µm capillary diameter, 0.2 m of OV-5 Stationary liquid phase.

**DMAs**: Low residence time (200 µs), high transmission (~50 %), high resolution (up to 110)³. The DMA₁ selects the explosive parent ion which enters the fragmentor, whereas the DMA₂ classifies the fragment ion generated.

**Fragmentor**: built from metal and ceramics is capable to reach temperatures up to 800 °C in order to break the more resilient species. The ion transmission inside the fragmentor takes place by electric fields, minimizing ion looses against the walls.

**Ion Detector**: For the time being a Mass Spectrometer working in single quadrupole mode is being used. However the m/z separation is not being used, representing the Total Ion Current (TIC). Once fixed the configuration and optimized the parameters the MS will be replaced by an electrometer.
## 2.1. Results

<table>
<thead>
<tr>
<th>Expl.</th>
<th>Parent Ion</th>
<th>Fragment. Temp. (°C)</th>
<th>Product Ion</th>
<th>Analysis interval (s)</th>
<th>GC Temperature (°C)</th>
<th>GC integration interval (s)</th>
<th>Integration time (s)</th>
<th>Gain (counts/pg)</th>
<th>Atmospheric Background (pg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EGDN</td>
<td>[M+Cl]^-</td>
<td>145</td>
<td>NO$_3^-$</td>
<td>0-6.5</td>
<td>110</td>
<td>2.7-3.9</td>
<td>1.2</td>
<td>133</td>
<td>22</td>
</tr>
<tr>
<td>NG</td>
<td>[M+Cl]^-</td>
<td>145</td>
<td>NO$_3^-$</td>
<td>6.5-16</td>
<td>110</td>
<td>8.5-9.7</td>
<td>1.2</td>
<td>1136</td>
<td>7.0</td>
</tr>
<tr>
<td>TNT</td>
<td>[M-H]^-$</td>
<td>400</td>
<td>[M-H]^-$</td>
<td>16-63</td>
<td>110</td>
<td>46.7-48.7</td>
<td>2.0</td>
<td>24079</td>
<td>2.4</td>
</tr>
<tr>
<td>PETN</td>
<td>[M+Cl]^-</td>
<td>189</td>
<td>NO$_3^-$</td>
<td>63-102</td>
<td>110</td>
<td>86-89</td>
<td>3.0</td>
<td>1126</td>
<td>6.3</td>
</tr>
<tr>
<td>RDX</td>
<td>[M+Cl]^-</td>
<td>280</td>
<td>NO$_2^-$</td>
<td>102-180</td>
<td>110</td>
<td>118-121</td>
<td>3.0</td>
<td>215</td>
<td>89</td>
</tr>
</tbody>
</table>
3. Application: Luggage screener

- Security screener for cabin luggage based on vapour analysis without removing electronic items in order not to slow down passenger flow.
- Inspection times similar to X-Ray screening.
3.1. Introduction

1. **0-6 s** The suitcase is sampled
2. **6-7 s** The filter with the sample is transferred to the thermal desorber (kept at 220ºC)
3. **7-12 s** Vapor analysis
4. **12-32 s** The filter is transferred to a cleaning system (kept at 250 ºC) and placed in waiting line for the next analysis
3.2. TRL4 prototype overview

- Development and test of a laboratory prototype with the following characteristics:
  - Sampling time: six seconds. Analysis time: six seconds.
  - Samples are taken on a dedicated sampling bench.
  - Samples are analyzed on a DMA-MS system.

```
<table>
<thead>
<tr>
<th>Sampling bench</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Filter holder</td>
</tr>
<tr>
<td>• Sampler</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Analysis bench</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Thermal desorber</td>
</tr>
<tr>
<td>• DMA-MS</td>
</tr>
</tbody>
</table>
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3.3. Hypotheses

- Vapour emission model for cabin luggage analysis.
  - The sampled item is a small, non-confined volume which behaves as a source of vapours to the environment.
    - The retention of vapours on the filter is a function of the sampling time, since only vapours generated during sampling can be captured.
  - Sampling a volume higher than required would dilute the emanated vapours without any favourable effect.
  - The key to achieve high performance is:
    - Achieve an optimal sampling flow, i.e., the minimum flow which captures all vapours emitted.
    - Implement strategies to stimulate vapour emission.
    - Route the emitted vapours towards the intake.
3.4. Hardware
3.5. Methods

- **Samples:** two ordinary carry-on suitcases (50 L) for blank and loaded (TNT and RDX) analysis.
  - 0.1 mg of explosive standard solution is spiked on a PTFE surface.
  - After the solvent evaporation, the remaining explosive is transferred onto a cotton patch, which is stapled on the loaded suitcase.
- **Different aspiration volumes.**
- **Analyzer:** SEADM DMA-MS/MS instrument.

3.6. TNT Results

- TNT
  - TNT emissions for a single fingerprint are easily detectable, independently of the volume sampled.
  - Loaded samples contain 100 times more explosive mass than blanks.
  - Most of the TNT is desorbed before the six-seconds mark.
3.6. RDX Results

- RDX
  - RDX is harder to detect than TNT, due its low volatility.
  - RDX is only detected at high aspiration volumes, whose higher flow velocities are able to route the vapours to the sampler and stimulate vapour emission.
  - Most of the RDX is desorbed before the six-seconds mark.
3.7. Conclusions

• TRL4 demonstrator was able to perform a fast screening of carry-on luggage pieces (six seconds for sampling and another six seconds for analysis).

• TNT and RDX emitted from a single fingerprint on the surface of a suitcase were detected. The detection in the case of TNT was clear. In the case of RDX it was weaker, however, to our knowledge, this is the first test reported worldwide where RDX fingerprints have been detected through vapour analysis.
Any questions?

Gonzalo Fernández de la Mora
gfdelamora@seadm.com

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