

Novel Sample Inlets for Measurement of Explosives and Threats Using a Miniature Mass Spectrometer

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Abstract

A next generation miniature chemical detection system has been developed using a cylindrical ion trap based mass spectrometer. There is ample evidence to suggest that the detection of explosives and other threat agents can be significantly improved using mass spectrometry via reduced false alarms, increased specificity, and ability to detect a wider range of threats when compared to mobility systems. However, mass spectrometers are inherently vapor sensors, which can present challenges as explosives are typically presented as particulate, and threats are commonly found in non-gaseous media (e.g., water).

This poster will describe several solutions developed by the authors to enable explosive particulate to be introduced to a miniature vacuum based instrument.

Miniature Mass Spectrometer

The instrument developed by the authors is a small (< 20 l volume, < 8 kg weight) mass spectrometer based on an ion trap architecture. In short, the instrument is capable of:

- 10 – 450 amu mass range (covering most explosives, TICs, and CWAs)
- < 1 amu resolution (FWHM)
- Sample-to-sample time: < 1 second (30 seconds with described pre-concentrator or desorber)
- Power consumption: < 45 W
- Sensitivity: < 200 ppb VOCs (< 1 ppb with pre-concentrator)

Figure X below shows three variants of the instruments.



Figure X – Photographs of 3 variants of 1st Detect miniature mass spectrometer including bench-top (left), handheld (center), and sub-component (right)

Figure X below shows representative spectra for several chemicals of interest.

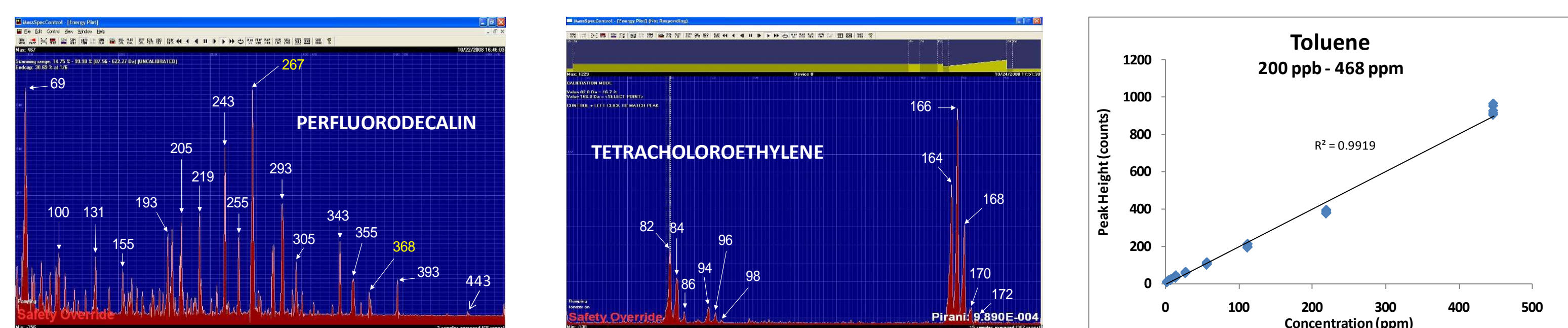


Figure X – representative spectra including perfluorodecalin (left), tetrachloroethylene (center), and a calibration for toluene (right) showing linear response over 200 ppb – 468 ppm

Evacuated Desorber

To enable particulate and ‘sticky’ substances to cross the vacuum barrier into the mass spectrometer, a novel thermal desorption system is being developed. The sample inlet allows collection of explosive particulate using a swipe method similar to those in use today. However, to allow transfer of the vaporized explosive particulate into the vacuum chamber, the desorber is configured to evacuate the volume prior to desorption thus allowing direct injection of the sample into the instrument without the need for external ionization or ion transport (e.g., ion funnel or quadrupole ion guide).

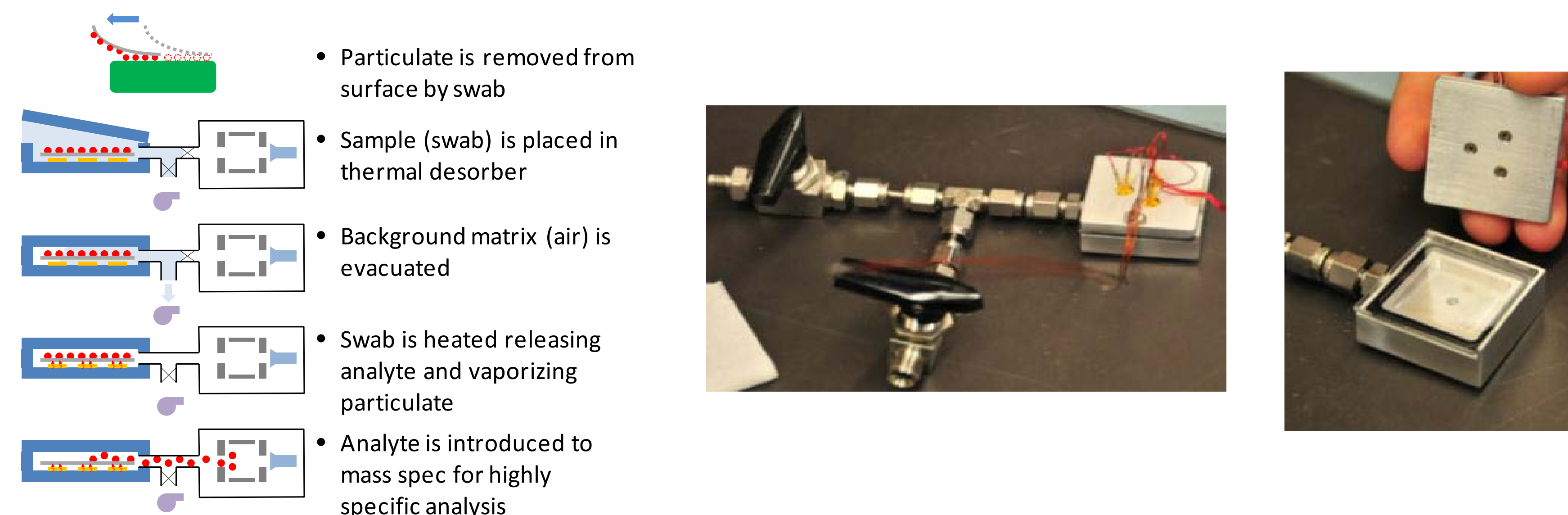


Figure X – schematic (left) and photograph (center and right) of evacuated desorber

Purge and Trap

To enable collection of threats agents from non-gaseous media, a novel purge and trap system has been developed utilizing the preconcentrator presented previously. A reduced pressure headspace is created over a liquid sample, and air bubbled through the system to release analyte. Preconcentration of the sample has been achieved with customized adsorption matrix in a geometry optimized both for maximum adsorption collection as well as efficient high yield desorption via direct introduction into the mass spectrometer at reduced pressure. The integrated design of the preconcentrator with the chemical detection system is targeted at sensitive analysis of vapor samples.

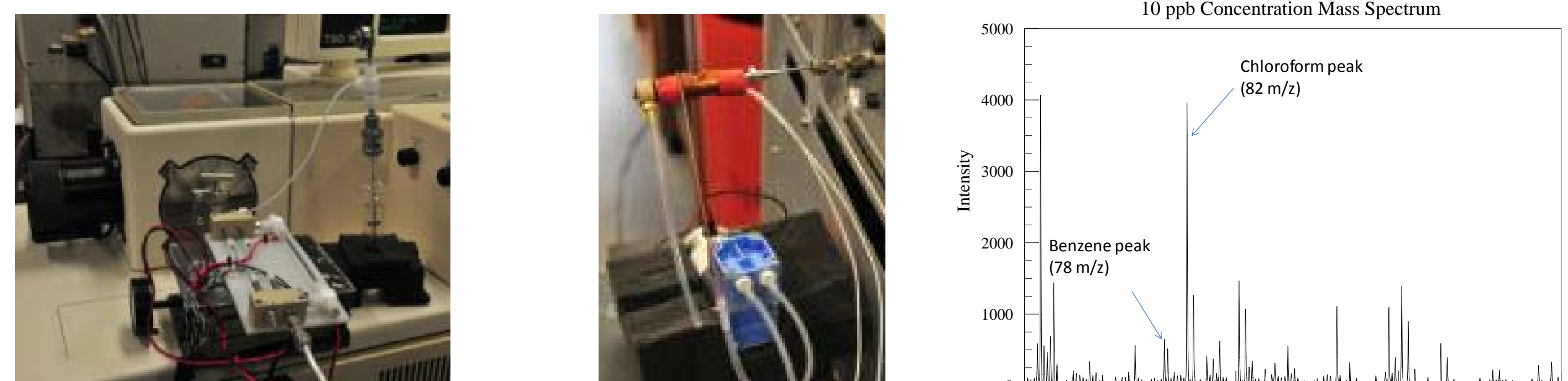


Figure X – Photograph (left and center) of water sampler and representative data (right) showing measurement of 10 ppb benzene and chloroform in water

Pre-Concentrator

A novel pre-concentrator has been designed that leverages the selective sorptive capabilities of advanced materials with a novel design that significantly reduces the analysis time compared to currently deployed instruments. In the design sorbent materials are placed in a tube with a heating element. The electrical leads of the heater is connected to a power supply controlled by a computer system. Because the tube housing the sorbent is evacuated thus minimizing the dead volume effect prior to thermal desorption, the overall concentration gain is a product of the adsorption and evacuation gains yielding a typical total gain in the range of 10⁴. Typical analysis times are less than 30 seconds.

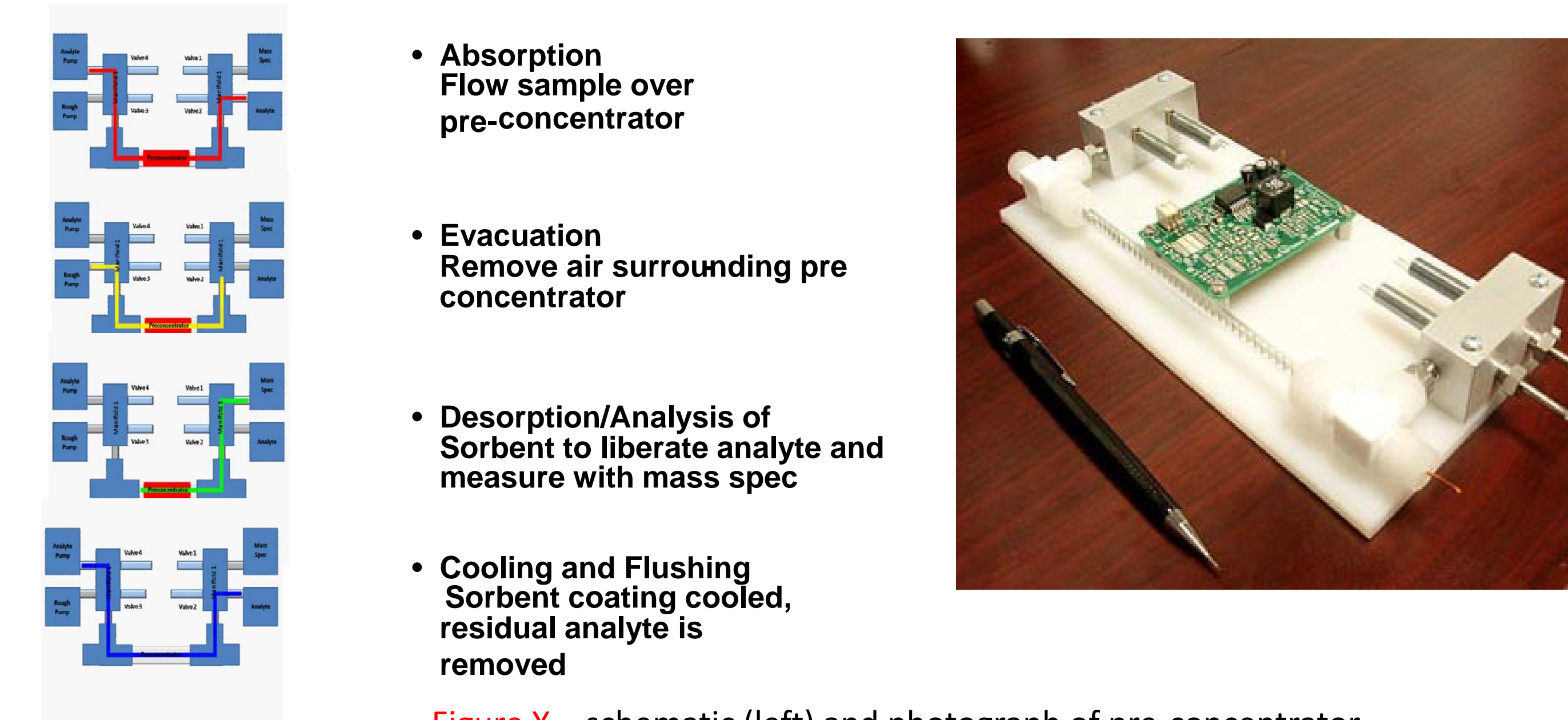


Figure X – schematic (left) and photograph of pre-concentrator

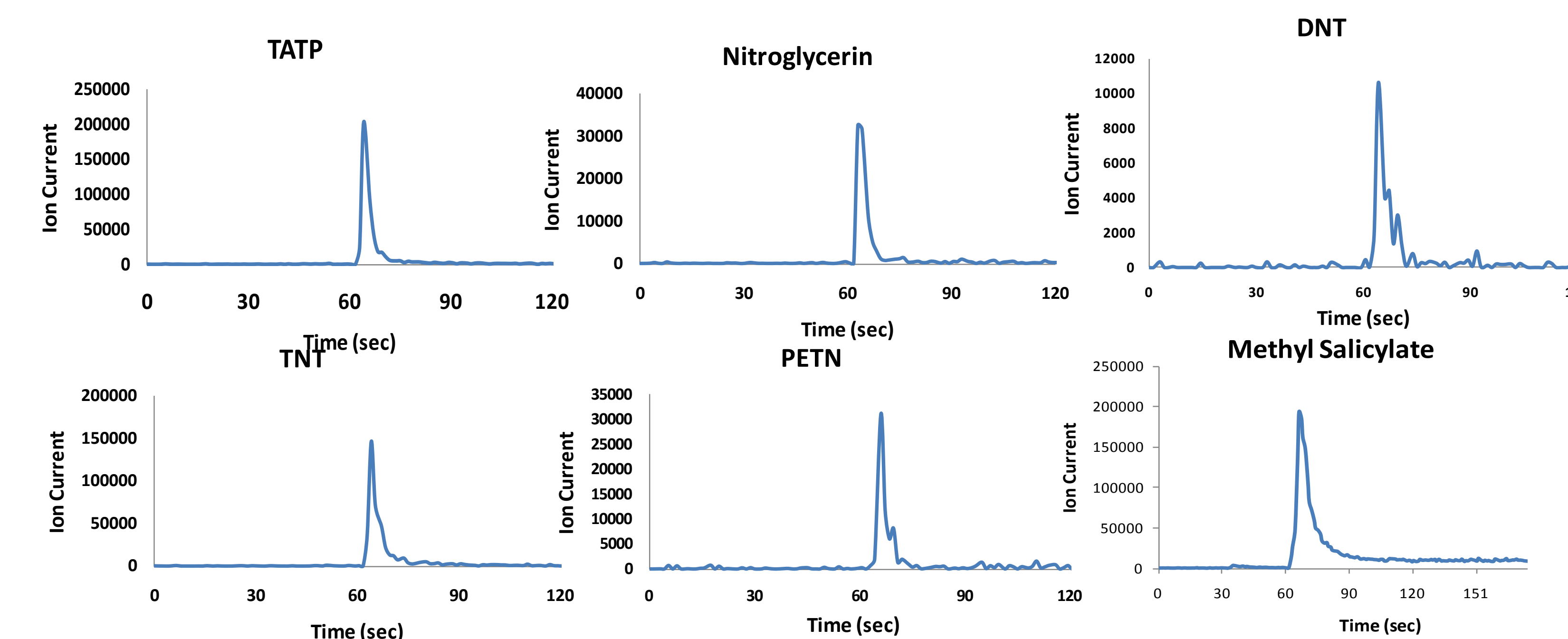


Figure X – Desorption profiles for representative explosives and CWA simulants

Acknowledgements

Portions of the work presented here were funded by the US Army Defense Threat Reduction Agency - Joint Science and Technology Office and the US Army Dugway Proving Ground under Contract No. W911S6-10-C-0012. Any opinions, findings and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the DTRA JSTO or Dugway Proving Ground.