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Low ppb detection of Chemical Warfare Agents (CWA) by Advanced Ion Mobility Spectrometer - AIMS

The ion mobility spectrometry (IMS) technique offers several advantages, including high sensitivity in the ppb range, fast response times in the millisecond range, compact instrument design, operation at atmospheric pressure, and the ability to separate isomeric compounds. These features make IMS highly suitable for real-time detection of hazardous chemical substances and chemical warfare agents (CWAs).

In this short report, we demonstrate the sensitivity and rapid response of IMS technology for the detection of Sarin (GB) and Sulfur mustard (HD). Both compounds were tested under controlled laboratory conditions in order to evaluate the detection capability, response behavior, and polarity-dependent ionization characteristics of the IMS system.

While Sarin is typically detected in positive ion mode due to efficient protonation, Sulfur Mustard is commonly detected in negative ion mode because of its favorable electron affinity and stable negative ion formation. The presented results demonstrate the capability of IMS technology for rapid and sensitive detection of highly toxic CWAs at low concentration levels.

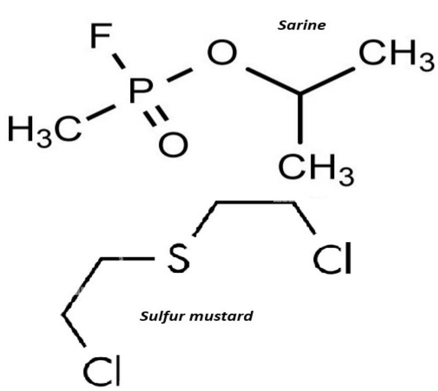

Figure1. Sarin and Sulfur mustard

Experiment

The **OEM-Advanced Ion Mobility Spectrometer** (**OEM-AIMS**) was used in this experiment. The operating parameters of **OEM-AIMS** are listed in Table 1.

Working pressure	**700 mbar**
Working temperature	**70 °C**
Drift Gas	**Zero Air**
Drift gas flow	**1000 mL/min**
Drift field intensity	**670 V/cm**
Sample gas flow	**300 mL/min**
Polarity	**Negative/ Positive**

*Table1. **OEM-AIMS** working parameters*

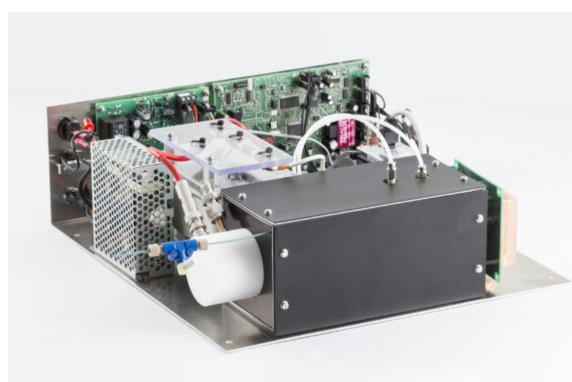

Figure2. OEM-AIMS

The OEM-AIMS system was purchased by IOS d.o.o. for integration into an UGV (Unmanned Ground Vehicle). Prior to

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the integration, the AIMS system was independently evaluated for the detection of chemical warfare agents (CWAs) at the Military Research Institute.

Each analyte was tested over the course of one day, and all measurements were independently validated using GC–MS analysis. The OEM-AIMS sample inlet was modified by IOS to minimize the memory effect.

Sarin was analyzed in positive ionization polarity using ammonia as a dopant in order to improve sensitivity and selectivity. The tested Sarin concentrations were 3.5, 10.5, 48.9, and 136 ppb.

Sulfur Mustard was analyzed in negative ionization polarity without the use of a dopant. The tested Sulfur Mustard concentrations were 12.9, 55.3, and 205 ppb.

Results and discussion

Sarin

The IMS responses for 3.5, 10.5, 48.9, and 136 ppb of Sarin is shown at figure 3.

As shown in Figure 3, Sarin produced a characteristic product ion peak with a reduced ion mobility of 1.54 $cm^2 \cdot V^{-1} \cdot s^{-1}$. The lowest concentration generated by the gas dilution system was 3.5 ppb. The results demonstrate that detection at this concentration was achieved without difficulty, indicating that a practical detection limit of approximately 2 ppb can be expected under real field conditions.

The response obtained for 136 ppb indicates that the dynamic range of the instrument may extend over approximately three orders of magnitude. Unfortunately, higher concentrations were not available for further evaluation.

It is also important to note that the IMS response was very fast, with practically no observable delay between analyte introduction and signal generation.

These results confirm that the OEM-AIMS system is highly suitable for rapid and sensitive detection of nerve agents in field-deployable applications.

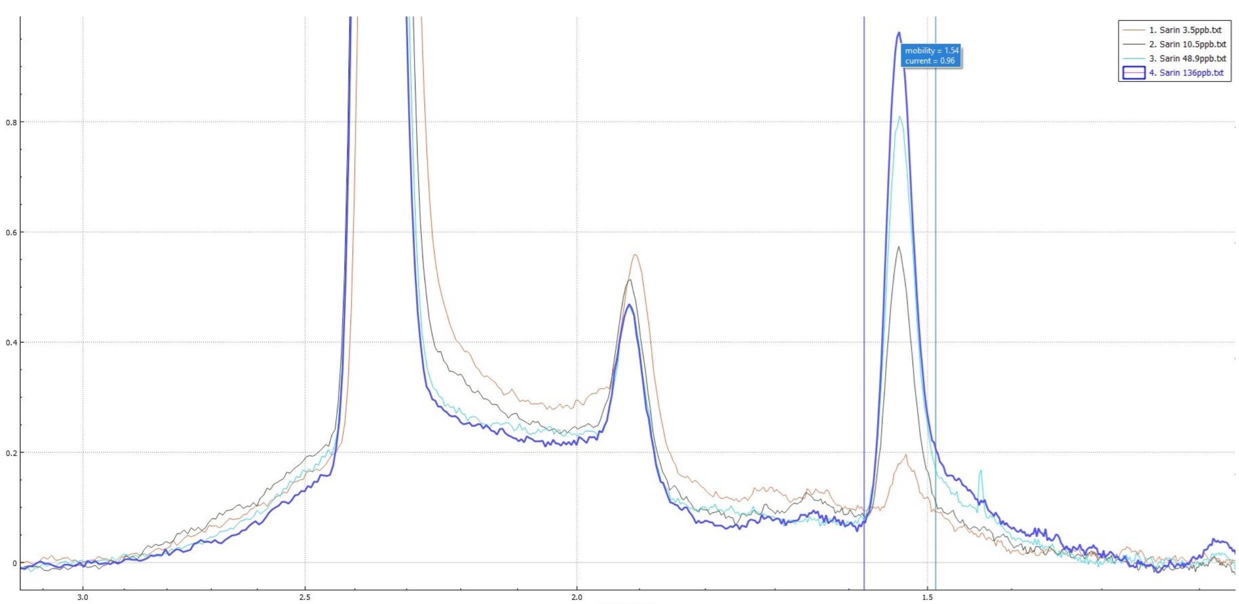

Figure 3. IMS responses for Sarin

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Sulfur Mustard

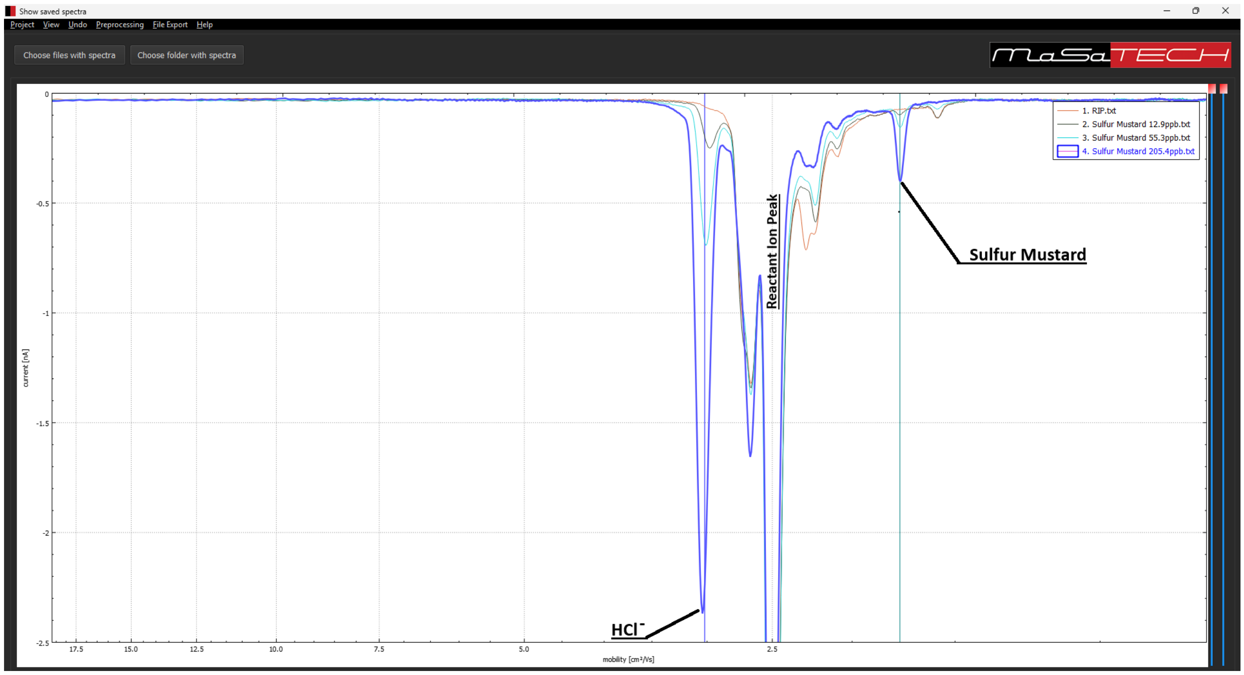

Figure 4. IMS responses for Sulfur Mustard

Sulfur Mustard was analyzed in negative polarity. The tested Sulfur Mustard concentrations were 12.9, 55.3, and 205 ppb. The IMS responses for this Sulfur Mustard concentrations are show at figure 4.

The IMS response for Sulfur Mustard resulted in the formation of two characteristic peaks: a peak with reduced ion mobility of 3.03 $cm^2 \cdot V^{-1} \cdot s^{-1}$ and a second peak with reduced ion mobility of 1.75 $cm^2 \cdot V^{-1} \cdot s^{-1}$.

The peak with reduced mobility of 3.03 $cm^2 \cdot V^{-1} \cdot s^{-1}$ was assigned to HCl^- ions formed from HCl generated during fragmentation of Sulfur Mustard molecules. The peak with reduced mobility of 1.75 $cm^2 \cdot V^{-1} \cdot s^{-1}$ was assigned to the Sulfur Mustard product ion peak.It should also be noted that the response intensity of the HCl^- peak was approximately three times higher than that of the Sulfur Mustard product ion peak.

The lowest prepared concentration was 12.9 ppb. At this concentration, both peaks were clearly observed, as shown in Figure 4. While the Sulfur Mustard product ion peak was close to the detection limit of the instrument, the HCl^- peak exhibited a strong response, indicating an estimated detection sensitivity of approximately 5 ppb.

These results demonstrate that indirect detection based on fragmentation products can significantly enhance the sensitivity of IMS detection for blister agents such as Sulfur Mustard.

Conclusion

The presented results demonstrate that the OEM-AIMS system is capable of rapid and sensitive detection of both nerve and blister chemical warfare agents. Reliable detection of **Sarin** and **Sulfur Mustard** was achieved at low ppb concentration levels with fast instrument response and good selectivity. The obtained results indicate that the developed IMS technology is well suited for integration into field-deployable unmanned detection platforms for CWA monitoring and early warning applications.