Industrial Safety Hazard Monitoring

Advancing Real-Time Detection of Hazardous Volatile Compounds with Mobile PTR-TOF

Hazardous compounds are used extensively across various industrial sectors, requiring stringent safety precautions to protect both workers and the public. We demonstrate that PTR-TOF, mounted on a mobile platform, is a versatile tool for real-time detection of hazardous emissions at sub-ppb levels.

Introduction

Most Toxic Industrial Compounds (TICs) have some degree of volatility and therefore can result in hazardous emissions that are easily transported through the air, posing additional risks for workers and the public. The toxicity of a compound directly correlates with its Occupational Exposure Limit (OEL), with more hazardous substances having lower OELs. For example, Trichloropropane (TCP) has an OEL of just 5 ppb, underscoring the need for highly sensitive detection methods.

Ionicon Analytik Gesellschaft m.b.H.
Eduard-Bodem-Gasse 3
6020 Innsbruck, Austria

Email: info@ionicon.com
Tel: +43 (0)512 214 800

Website: www.ionicon.com
UID: ATU 45012203
FN: 172007b

Several critical applications highlight the need for effective detection and monitoring:

1. **Leak Testing**: Pipelines, often composed of numerous flanges, require rigorous leak testing. While initial leak testing is essential, continuous monitoring would be ideal, as factors like gasket failure, corrosion, mechanical damage, and thermal or mechanical cycling can cause leaks over time.
2. **Clearance Testing**: Before servicing, parts need to be tested to confirm the absence of harmful compounds, ensuring safe handling.
3. **Dismantling Industrial Complexes**: During the dismantling of industrial facilities, the release of residual toxic substances poses significant health risks to workers and the environment. Continuous monitoring of hazardous emissions is vital to ensure safety throughout the process.

Classical **offline sampling** followed by **GC-MS** analysis in a laboratory can cover a broader range of compounds with low detection limits. However, GC-MS is labor-intensive, time-consuming, and the results are only available the next day, and thus delays the feedback needed for rapid decision-making. Moreover, situations may change quickly and especially leaks can occur at any time, putting workers at risk.

In contrast, **real-time monitoring** offers immediate feedback and enables swift intervention to protect worker safety and prevent environmental contamination. However, currently no portable analyzers are available that can reliably detect a wide variety of hazardous compounds at low concentrations. Optical methods like **NDIR** and **CRD** are limited to small molecules such as Methane (CH_4), Hydrogen chloride (HCl), and hydrogen sulfide (H_2S).

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Mass spectrometric (MS) methods offer numerous advantages, including the ability to detect a wide variety of compounds at low concentrations. However, quadrupole-based MS systems typically suffer from low mass resolution, which limits their specificity, and can take up to a minute to complete a full scan. This limitation is addressed by Proton-Transfer-Reaction Time-of-Flight Mass Spectrometry (PTR-TOF-MS), which combines high mass resolution and real-time detection, allowing for the identification of a broad range of compounds at sub-ppb levels. For instance, a full spectral scan with PTR-TOF-MS can be completed in less than 1 second while maintaining sub-ppb detection limits. Despite these capabilities, MS-based systems have traditionally been stationary, laboratory-based instruments designed primarily for scientific research.

In recent years, IONICON has advanced its PTR-TOF systems for industrial applications, emphasizing high stability, reliability, and ease of use. In a joint project between Olin and IONICON, the PTR-TOF system has been further modified specifically for real-time detection of hazardous volatile compounds in mobile settings, and has been deployed and tested in the field.

Methods

For this purpose, IONICON has modified its robust Proton Transfer Reaction-Time of Flight Mass Spectrometry (PTR-TOF) system, a PTR-TOF 1000. This system has been optimized for hazardous compound detection with **a 100-meter long sampling line**, complemented by an additional pump to maintain rapid sample transfer from distant locations to the analyser.

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Figure 1: Operator checking a manhole for emissions using the live data streamed to a tablet display from the mobile PTR-TOF instrument. Picture credit: Olin.

IONICON's Automated Measurement and Evaluation (AME) software was specially trained to **detect a predefined list of hazardous compounds** but also monitors all compounds present in the air, including those not pre-identified on the list.

To further enhance the system's mobility and adaptability, the PTR-TOF was mounted on a **mobile platform** in collaboration with Olin. This setup allowed the device to be positioned close to the sampling sites. Data collected from the system was streamed wirelessly to a tablet.

Results

For this demonstration the system was mounted on a simple but effective mobile platform. This enabled the PTR-TOF system to be deployed within the sampling radius of various points. The long sampling line, supported by an additional pump, allowed for **rapid transfer of gas samples**, providing near real-time results. Even high concentrations of "sticky" compounds, such as Phenol, were quickly purged from the system, ensuring reliable and continuous monitoring without delays due to residual contamination.

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Figure 2: Operator locating the source of an emission using the live data streamed to mobile display. On the left, the simple but effective mobile PTR-TOF platform can be seen. Picture credit: Olin.

The real-time capability allowed not only for the probing of specific points but also for "**sniffing around**", helping to pin-down the sources of an emission, such as leaks, with greater precision. **Data streamed to the tablet provided direct feedback**, enabling the operator to adjust the sampling location in real time.

The **handcart used as a mobile platform** for this demonstration proved effective, with its soft wheels providing sufficient shock absorption during transport. The PTR-TOF demonstrated its robustness and suitability for the application. In the second phase, Olin plans to implement the **PTR-TOF with a multi-channel sampling unit on**

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an electric vehicle, enhancing mobility and ensuring continuous power to the system.

Conclusion

For detecting a broad and dynamic range of hazardous compounds at low concentrations, real-time monitoring technology like **PTR-TOF is invaluable**. It enables **rapid assessments and immediate feedback**, significantly accelerating the process compared to traditional methods. This capability is especially critical in industrial settings, where timely detection is essential for ensuring safety.

In contrast to conventional leak testing, where pipelines are pressurized with a probe gas such as helium—requiring a process interruption—**online leak testing** allows for continuous, in-process monitoring. Leaks can be detected by "sniffing" the process compounds directly, without halting operations.

The flexibility of IONICON's AME software, which operates in multiple modes and monitors a wide spectrum of compounds, enhances the system's specificity for hazardous substances, thereby minimizing false positives. Moreover, since a PTR-TOF spectrum captures the full range of detected compounds, the system can be **easily adapted to monitor new or emerging hazards** through software updates.

Further technical improvements, such as integrating the PTR-TOF with an electric vehicle platform, are planned to enhance mobility and ensure continuous power supply during field operations. This advanced solution is essential for **protecting both workers and the public** in environments where hazardous compounds are present, while **minimizing interruptions to industrial processes**.

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