# SMART DIGITAL SYSTEMS FOR IMPROVING WORKERS' SAFETY AND HEALTH

# SMART SENSORS FOR HAZARDOUS GASES

# DESCRIPTION OF THE SMART DIGITAL SYSTEM FOR OSH

## 1 Introduction

Smart digital systems and technologies entering EU workplaces are reshaping work environments for workers and employers alike. Innovations in smart wearables, exoskeletons, artificial intelligence (AI), machine learning (ML), internet of things (IoT), virtual and augmented reality (VR and AR), among others, are giving new opportunities for preventing and responding to workplace risks.

As part of EU-OSHA's occupational safety and health (OSH) overview programme (2020-2023)[1], EU-OSHA has examined the challenges and opportunities of smart digital tools and monitoring systems for improving workers' safety and health. These systems, leverage digital technology to collect and analyse data in order to identify and assess risks, prevent and/or minimise harm and promote OSH.[2] EU-OSHA has categorised such systems into proactive (preventive) and reactive, albeit acknowledging the potential overlap between the two.[3] EU-OSHA further provided an overview of the risks and opportunities associated with these systems[4] and explored the workplace resources that could ensure their safe and healthy use.[5]

In order to investigate the practical implementation of smart digital tools and new OSH monitoring systems for improving workers' safety and health, EU-OSHA has developed a number of case studies. This set of case studies includes both cases of smart digital systems at the level of design/development and cases of companies implementing the systems. The case studies accordingly investigate aspects related to the design/development stage and to the implementation stage. OSH aspects including worker's involvement was considered in all case studies taking into account the type of case study. Further all case studies look at possible drivers, barriers and success factors for safe and effective implementation.

To develop these case studies, apart from desk research, a number of interviews with key informants were conducted, including workers' representatives, safety officers, employers and representatives of industry associations. In addition, at company level, up to five interviews were conducted with operators, data protection officers, health and safety engineers, managers, work councillors and technology officers. The interviews had a duration of 1-1.5 hours each and were performed in the participants' native language, if possible, or alternatively in English, an interview guide, while the results of the interviews were anonymised. The case studies referring to designers' results do not contain detailed information on workplace implementation, as there has been limited collection of information from companies in which the systems are installed.

In total 15 cases were identified, and preliminary information was collected for these through a questionnaire, hereafter, nine of them were further developed into case studies.

[1] For more information, see: osha.europa.eu (n.d.) Digitalisation of work. Available at: https://osha.europa.eu/en/themes/digitalisation-work

[2] EU-OSHA (2023). Smart digital monitoring systems for occupational safety and health: uses and challenges, https://osha.europa.eu/en/publications/smart-digital-monitoring-systems-occupational-safety-and-health-uses-and-challenges

[3] Ibid.

[4] Ibid.

[5] EU-OSHA (2023). Smart digital monitoring systems for occupational safety and health: workplace resources for design, implementation and use, https://osha.europa.eu/en/publications/smart-digital-monitoring-systems-occupational-safety-and-health-workplace-resources-design-implementation-and-use

# 2 General company description

This case study refers to smart sensors for hazardous gases, developed by a German manufacturer that is an international leader in the fields of medical and safety technology. The manufacturer produces a range of products, including breathing apparatuses, fixed and portable gas detectors, respiratory protection equipment, underground safety gear, and more, for various industries. Operating worldwide, the manufacturer employs around 15,000 people.

The case study also includes an example of how a United Kingdom-based company specialising in catalyst-handling operations, implements these sensors. Founded in 1973 this company initially aimed to offer specialised catalyst-handling services to the ammonia industry.

## 2.1 System description

### *2.1.1 What is the system about?*

The occupational safety and health (OSH) monitoring system examined in this case study is a smart **system for monitoring of hazardous gases, a multi-gas detector, as part of an infrastructure that connects it to a cloud platform**.

Gases can be divided into three categories: flammable, toxic and asphyxiant. Categories can overlap. For example, carbon monoxide (CO) can be both flammable and toxic. However, distinctions are important as the hazards and regulations for each gas are different, as are the sensor types required to identify them.

**Figure 1: Gas categories**

| Flammable | Toxic | Asphyxiant |
|---|---|---|
| Fire and/or explosion risks | Poisoning risks | Suffocation risks |
| Methane, butane, propane | Carbon monoxide, hydrogen, chlorine | Oxygen deficiency: oxygen can be consumed or displaced by another gas |

Gases can be odourless, tasteless and invisible. They are present in multiple applications and processes in industrial settings, and they can have **negative effects on the safety and health of workers**. One example is CO, which can be found in marine, mining, oil and gas, and several other industries. High levels of exposure to CO can cause suffocation and death. For example, in the United States, CO inhalation led to most workplace fatalities between 2011 and 2017. Comparable statistics for the European Union are not available.

The multi-gas detector monitors flammable and toxic gases and vapours as well as oxygen and informs workers in real time if the concentrations are becoming hazardous for their health. Next, gas detectors are connecting to a cloud platform, with the objective to manage them as an integrated part of the OSH management.

## *1.2.2 How does the system look and work?*

The device's configuration is intuitive. A large display shows the values of the atmospheric conditions at a glance, while a visible alarm alerts workers if these exceed the so-called **threshold limit values (TLVs).**

TLVs are the 'exposure limits to which it is believed nearly all workers can be exposed day after day for a working lifetime without ill effect'.[6]

Occupational exposure limit (OEL) values in different industries are set by competent national authorities or other relevant national institutions, as limits for concentrations of hazardous compounds in the workplace air.[7]

The smart sensor system features **different types of sensor technologies**, the tool offers various monitoring possibilities.

While TLVs provide recommended exposure limits based on scientific evidence, OELs serve as legally enforceable standards set by regulatory agencies.

DID YOU KNOW?

Gas detectors use three types of sensors: catalytic, electrochemical and infrared. Each of these types has its strengths and limitations. Selecting the right one depends on the specific application in an industrial setting (for example, confined vs non-confined space) and on the gas to be monitored. For example, an infrared sensor is superior to a catalytic sensor for monitoring specific gases: it is poison-free, it cannot develop faults that lead to a safety-critical situations and it operates in inert spaces under different temperature, pressure, and humidity conditions. However, compared to a catalytic sensor, it has higher maintenance costs and is not able to monitor hydrogen or specific hydrocarbons, for example, chlorinated or fluorinated ones. Modern smart digital systems often combine different types of sensors, to offset their limitations.

Next, with advancements in sensor and wireless technologies, an IT infrastructure has been developed to integrate the **smart gas monitoring systems into existing OSH frameworks within organisations**.

In Figure 2 an overview of possibilities is provided.

**Figure 2: Uses of the connected smart monitoring systems to the cloud**

| **Real-time monitoring** | **Fleet management** | **Compliance** | **Holistic picture in facilities/efficiencies** |
|---|---|---|---|
| Real-time gas readings in plant facilities. | Information on device status. | Information on compliance with safety protocols. | Integrating information from different safety systems for a holistic safety and health picture. |

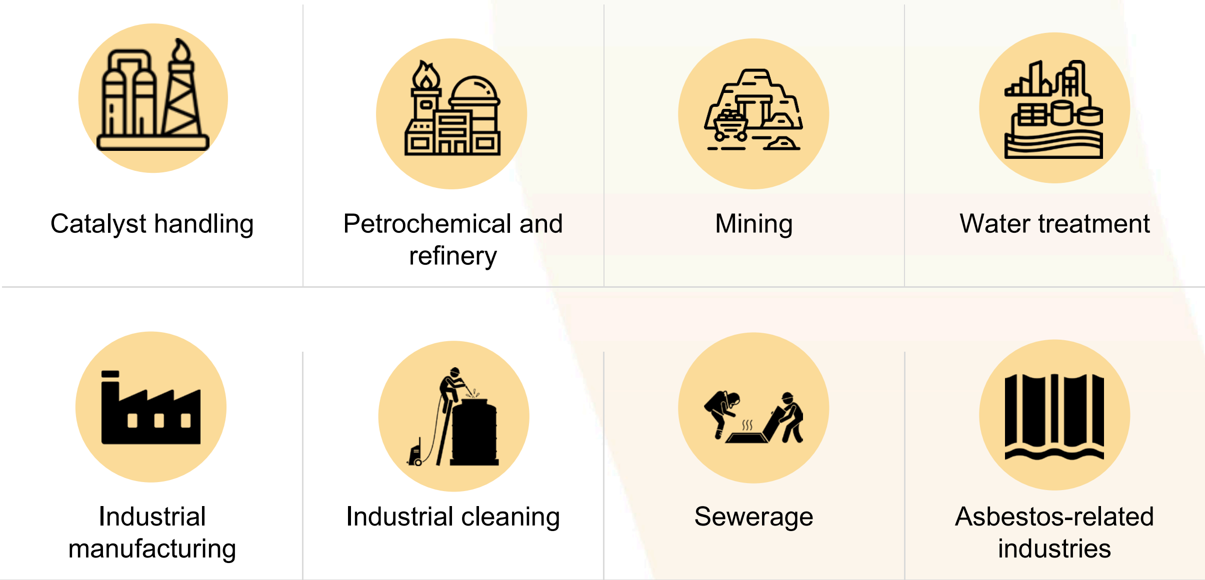
The development of an infrastructure that connects the (fixed and portable) gas detectors to a cloud platform supports OSH managers to manage their fleet, by providing them with live geolocated measurements from the gas detectors in facilities, and by checking which equipment is ready for use through the cloud platform. This is facilitated by Bluetooth technology, which transmits information from the gas detectors to the cloud.

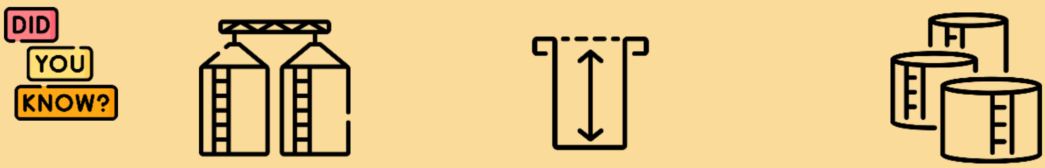
[6] Honeywell (2013). Gas book, https://sps.honeywell.com/content/dam/honeywell-edam/sps/his/en-us/documents/services/sps-safety-services-gas-book.pdf, p. 24.
[7] Honeywell (2013). Gas book, https://sps.honeywell.com/content/dam/honeywell-edam/sps/his/en-us/documents/services/sps-safety-services-gas-book.pdf, p. 22.

## 2.2 Examples of use

The primary use of the gas detector is **personal monitoring**. The system is worn on workers' clothing and informs them about gas-related risks in their work area. However, the gas detector can also offer **area monitoring through remote sampling measurement**. For instance, confined spaces such as pits, tanks, or grain silos may contain dangerous gases that OSH professionals must detect before allowing workers to enter. To address this, the system can connect to a pump for relevant measurements. The choice between **a mobile monitoring system and a fixed one depends on the application.** For example, in a storage area for nitrogen, where workers may frequently enter and exit, a fixed monitoring system is the logical choice. Figure 3 highlights some sectors where gas measurement is relevant.

**Figure 3: Potential applications of gas detection**




In confined spaces, measurements are conducted at various levels to ensure safe entry. For instance, certain gases, being lighter than air, tend to accumulate at the uppermost part of a structure such as a tank. In such cases, taking measurements solely at the bottom of the tank would not be adequate.

Based on an interview with a UK-based company specialising in catalyst-handling operations that has been using the gas detector system, gas detection is only one aspect of their broader measures to protect the safety and health of their workers. Specifically, before initiating a catalyst-handling operation, the company typically first requests safety data sheets from the refineries to perform a **risk assessment**. The risk assessment examines atmospheric and physical hazards relating to the proximity of the job, the surrounding environment, and so on. Based on this, the company determines the TLVs for the different gases that might be present in an operation, as well as the additional safety measures that must be taken to ensure the health and safety of the workers, such as breathing apparatuses, measures for skin protection and heat stress monitoring.

In general, gas monitoring operates continuously, 24 hours a day. There is always an active gas detector in operation, along with two backups: one to replace the active detector when its batteries are depleted and another as a contingency in case the backup fails.

# 3 System implementation: drivers and barriers

## 3.1 Motivators and goals

Monitoring hazardous gases is a legal requirement for most high-risk industries in the European Union. Such monitoring is done using **fixed** or **portable single**- **or multi-gas detectors** leveraging **sensor** and other kinds of technologies.

Unlike early monitoring systems, gas detectors are now increasingly sophisticated and interconnected with other safety systems. For example, some portable gas detectors can **transmit real-time gas readings, alarms, man-down statuses, compliance statuses, and locations to the computer or mobile device** of safety or operations managers. At the same time, companies manufacturing these systems are increasingly exploring ways to integrate them to other safety applications in industrial sites, aiming to provide plant-wide insights on OSH.

The smart sensor, as examined in this case study, is one of the smallest portable multi-gas detector systems, capable of measuring up to six gases using infrared-tech and electrochemical sensors. It also provides an example of this system's application in the broader OSH management of catalyst-handling operations.

## 3.2 Drivers

Recently, the German manufacturer has been expanding the capabilities of its smart monitoring systems. Adopting a bottom-up approach with its implementing companies, the clients, the manufacturer has been exploring ways of leveraging new technologies **to add value to the implementing company's safety and health procedures**. This has led to the development of infrastructure that connects its fixed and portable gas detectors to a cloud platform. As a result, safety and health managers can receive live geolocated measurements from the gas detectors in facilities and manage their fleet, including checking which equipment is ready for use through the cloud platform. This is facilitated by Bluetooth technology, which transmits information from the gas detectors to the cloud.

Additionally, the manufacturer is working on **integrating information from different safety systems into a single cloud platform** together with its clients through **technology-discovery workshops.** This integration can extend beyond gas detector data, encompassing process-related details, such as whether a worker has retrieved the necessary equipment from **a workplace vending machine** before entering a restricted area, or whether gas detectors have been bump-tested. Looking ahead, the manufacturer anticipates a growing trend among employers and organisations seeking to use such monitoring systems for broader purposes, such as measuring atmospheric conditions within plant pipes to ensure efficiency, for example, after restarting a reactor. Additionally, it expects a rise in demand for monitoring emissions in emerging industries like energy transformation and transition sectors.

Workers **are consulted before selecting** a gas detector for a specific application. Typically, safety and health managers, along with technical engineers, participate in this decision-making process. These individuals are also the ones who typically receive training from the product manufacturer to carry out essential operations on the gas detectors. At the same time, **workers on the ground also receive training** on the gas detectors.

## 3.3 Barriers

Since the company operates in hazardous atmospheres that are immediately dangerous to life and health (IDLH), its primary consideration when selecting a gas-detection system is to ensure its **robustness across various operations and** having a system that **can accurately and seamlessly measure** the intended gases, especially in remote areas, and including the ability to combine sensors for specific gas measurements. For this **strong support from the manufacturer** in providing **accessible training for staff members is crucial**.

Although **time and costs restraints, input of workers** is needed when selecting a gas detector for a specific application. Typically, safety and health managers, along with technical engineers, participate in this decision-making process. These individuals are also those who usually receive training from the product manufacturer on essential operations, such as calibration and bump-testing.

Next, integrating smart gas monitoring systems into existing OSH frameworks within organisations by **connecting them to the cloud** presents certain challenges. Figure 4 presents some of the key challenges identified in this case study. These challenges depicted are not unique to the manufacturer's system but common to many similar products.

**Figure 4: Challenges of connecting smart monitoring systems to the cloud**

| Development costs for product manufacturers | Training costs for OSH professionals | Technological barriers | Migration costs |
|---|---|---|---|
| Developing software/hardware bespoke solutions typically involves high costs for product manufacturers. | APIs simplify safety data, but training OSH professionals to analyse information from different safety systems can be costly. | For example, there might be concerns about Bluetooth signal interference with a gas detector operating within a vessel. | New connectivity options might not fully support older devices, leading to increasing costs for companies. |

# 4 OSH impact

This section outlines the primary insights for developing and safely implementing smart sensor systems to monitor hazardous gases.

## 4.1 Opportunities

Using smart sensors for personal or area monitoring can improve worker safety and health by both proactive and reactive means.

**Reactively**, these sensors can enhance the speed of **emergency responses**. For example, in the event of a gas leak, smart sensors can send immediate alerts to OSH professionals, enabling them to initiate emergency protocols, such as shutting down equipment, and assisting workers in evacuating dangerous areas.

Proactively, next to informing workers in real time if the concentrations of these atmospheric conditions are becoming hazardous for their health, the smart sensors can help organisations to **improve their safety practices through the collecting of workplace data and trends**, based on automatically generated reports on gas levels, saving time and reducing human error in documentation.

The remote monitoring of hazardous environments (for example, through attaching a pump to a gas detector), allows **safety managers to oversee conditions from a safe distance**, that could **reduce the need for onsite inspections in dangerous areas.** The **integration** of these systems with other safety measures in industrial plants could allow further promote OSH. For example, as described earlier, the German manufacturer was exploring the possibility of **connecting smart sensors to 'vending machines' that dispense safety equipment and clothing for workers**. Such developments could **improve** compliance with safety protocols, simplify audits, as well as enable health managers to obtain a comprehensive overview of safety measures throughout an industrial plant, thereby boosting the overall safety and health of workers.

## 4.2 Challenges

Most often, smart sensors for personal or area monitoring are used in life-critical operations. Therefore, they have been tried and tested in high OSH risk sectors for several years, with technological advancements making some types of these sensors nearly fail-safe.

However, challenges remain in the smart monitoring of hazardous gases. These challenges often arise **from environmental conditions, such as temperature, pressure and humidity**, as well as from sensor drift and **degradation over time**, all of which can affect accuracy. In this regard, it is important to implement robust maintenance and replacement plans and have trained professionals available to calibrate the sensors.

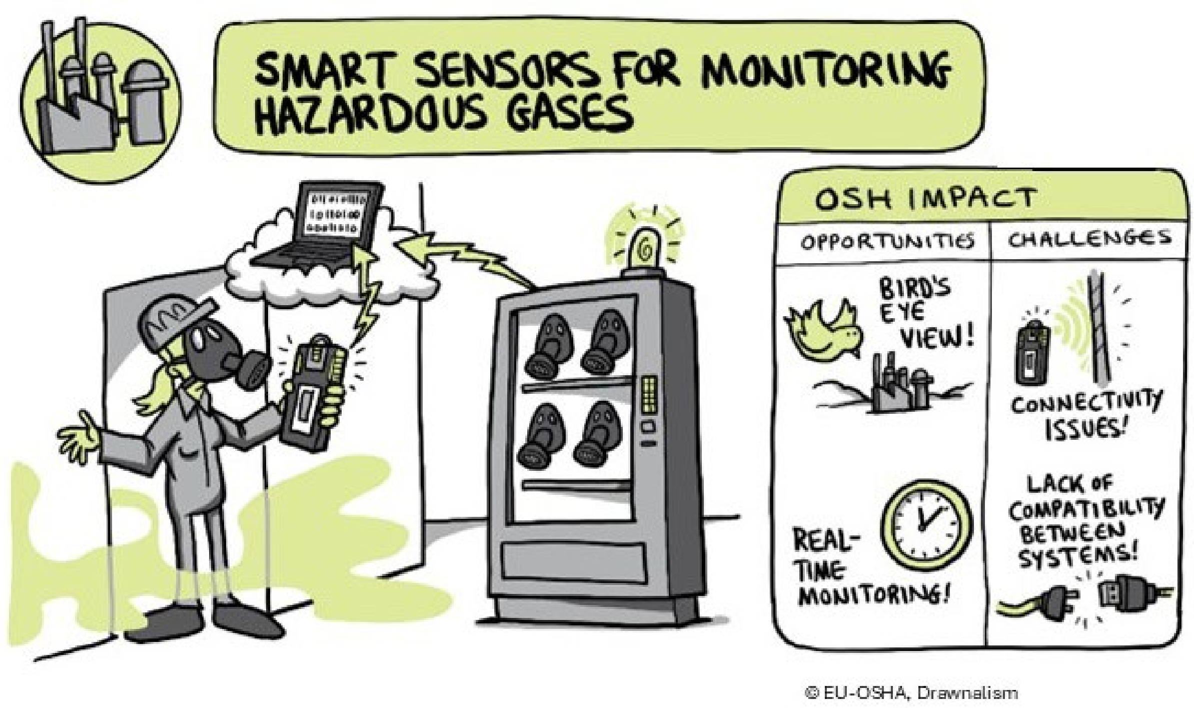
Further, the possibility of tracking workers via GPS could lead to **workers' privacy concerns**. Moreover, workers could become too relying on alarms. Another challenge is the potential for **false alarms**. Setting the sensitivity of sensors too high might lead to frequent false alarms, while setting it too low might cause dangerous conditions to go undetected.

Looking to the future, as technology advances and these systems have increasing capabilities to connect with other safety systems, new challenges may arise. One such challenge is **training OSH professionals to manage the growing volume of data**, as well as ensuring that **overreliance on these systems** does not overshadow other plant-wide critical safety procedures.

Finally, as these systems transition from 'operations' management' to 'information management' and become more connected to networks, **cybersecurity** might also become an important concern. Therefore, implementing robust measures to protect data and prevent unauthorised access will be essential.

Figure 5 presents a cartoon-style depiction of how such an integrated system could look.

**Figure 5: Smart sensors for monitoring hazardous gases[8]**




# 5 Takeaways for development and implementation

This section outlines the primary insights for developing and safely implementing smart sensors for monitoring hazardous gases.

**For the development of smart sensors for monitoring hazardous gases product manufacturers should consider:**

[8] The challenges and opportunities illustrated in the figure are not unique to the manufacturer's system but common to many similar products.

- establish rigorous mechanisms to ensure the accuracy of the sensors under different environmental conditions;
- collaborate with implementing companies (clients) on workers' needs early on, and provide ongoing support and guidance to OSH managers and users, as these systems often require customisation for specific workplaces; and
- explore avenues to improve these systems by improving their integration with other OSH management systems, to form a holistic view of safety and health across all facilities of a plant.

**For safe and healthy implementation of smart sensors for monitoring hazardous gases organisations should consider:**

- follow a thorough risk assessment of workplace hazards and embed smart sensor systems within this risk assessment in cooperation with the workers (end-users);
- involve workers and their representatives in the implementation process;
- put into place back-up sensor systems in case the primary ones fail or run out of battery, to continue operations; and
- maintain rigorous health and safety protocols, particularly in life-critical operations.

# List of abbreviations

| | |
|---|---|
| AI | Artificial intelligence |
| AR | Augmented reality |
| IDLH | Immediately dangerous to life and health |
| IoT | Internet of things |
| ML | Machine learning |
| OEL | Occupational exposure limit |
| OSH | Occupational safety and health |
| TLV | Threshold limit values |
| VR | Virtual reality |

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