A SIXTH

René Braun, Grandperspective GmbH, Germany, identifies a new way of helping manufacturers with gas leak detection in the fertilizer industry.

SENSE

Rattlesnakes have an extraordinary sixth sense. Their so-called pit organ is a membrane that is sensitive to infrared radiation. It allows them to strike prey accurately and warns them of dangerous aggressors even in the dark of night and well before they can smell them. In the fertilizer industry, a similar technique has been designed to help manufacturers stave off the risks of hazardous gases.

This new technique can complement current concepts of gas leak detection or even completely replace them. This article explores why traditional techniques no longer meet the challenges of a growing industry and presents an innovative solution.

A growing risk

In the industry's collective mind, the production, handling and transportation of all kinds of gases is closely linked to well-established standards, precautionary measures, and safety protocols. This attitude may lead to a firm, albeit increasingly false, sense of security.

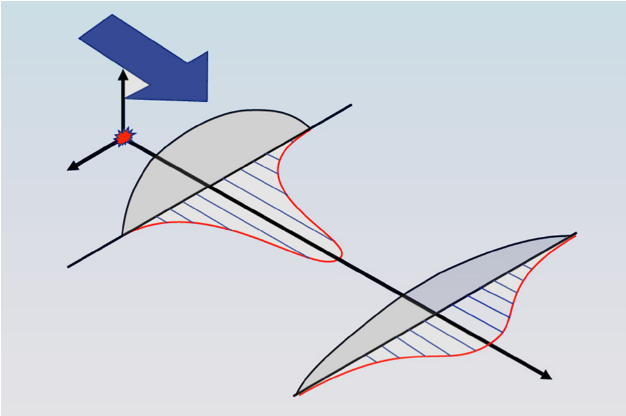

Figure 1. Gas cloud distribution in both propagation direction and perpendicular to the propagation. The distribution shows that a concentration value without the position within the distribution function can only have limited validity.

Figure 2. Field experiment with methane release: it is practically impossible to place a gas sensor in the best position. (Distribution of a cloud caused by a small leak [20 g/min.], measured with a Bruker spectrometer).[2]

In line with the steep and steady growth of the fertilizer market, the volume of hazardous gases processed in the chemical industry has massively expanded for decades. Ever more compact production sites, longer turnaround times and reduced staff numbers exacerbate the hazards. The space available to distance one area with a risk of hazardous gas release from another area where this gas may cause serious harm is getting increasingly limited. And with growing residential neighbourhoods as well as with busier motorways, railway lines and flight paths, the risk potential is increasing all the time. At the same time, according to a study carried out by the UK Health and Safety Executive (HSE), 30% of all major gas leaks go unnoticed.[1] In fact, such releases are already causing serious damage and even the loss of lives: in 2019 the value of insurance claims due to large accidents ran into billions of euros in Europe and the US alone. Most of those accidents were caused by unnoticed releases of flammable or otherwise hazardous gases. China reported 800 incidents related to unknown gas releases, with more than 400 fatalities in 2019.

For these reasons, a concept to prevent dangerous gas releases should not just be an ethical duty – it also makes plain business sense. Grandperspective has developed a solution for the early detection, assessment and localisation of hazardous gas releases that can cover entire industrial sites.

Sniffing out a cloud

The common approach to detecting leaks from unknown sources is to equip the most likely points of release with various kinds of measurement devices, usually gas detectors. A gas detector is a point sensor, a 'technical nose' that provides gas concentration values. Its output is a simple value which to interpret seems to be very easy, as flammability and toxicity are commonly measured relative to concentration. Therefore, gas detectors create a sense of security. However, this is not entirely justified, as their findings are limited to single points of contact and fail to deliver the big picture. This approach can never be fully effective, as it would require the costly deployment of sensors at each and every potential point of release. Furthermore, permanent staff and materials expenses are required to calibrate and maintain equipment, which is not very efficient. The network for the collection of measurement data and software for the simulation of likely propagation of a leaked gas add further cost to both the initial investment and operations. Typically, the trade-off between a perfect gas detector network and affordability will result in patchy and sparse data, the relevance of which operating staff will find difficult to interpret. The correct interpretation hinges on the placement of the sensors. Even when the gas concentration values are sound and valid for one particular point, they cannot fully reflect the hazard potential of the situation as a whole.

By design, a single point measurement cannot provide information of the total amount of gas released. While gas concentration is a valid situation assessment for confined interiors, in the open field gas is diluted in the direction of propagation and in all three dimensions. At its point of release, a gas concentration is

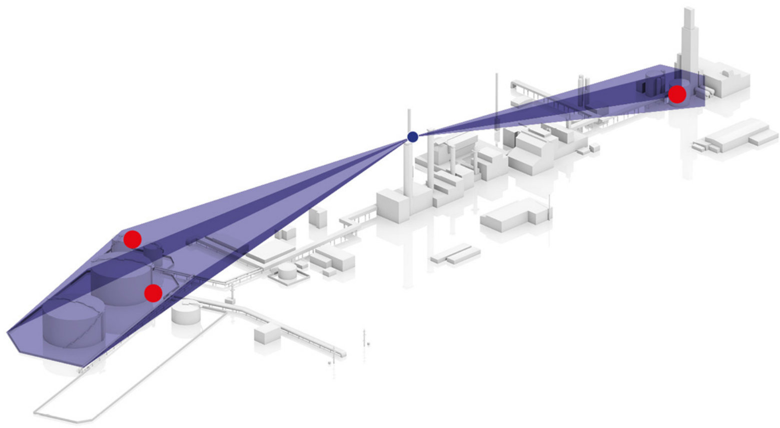

Figure 3. The remote monitoring principle: detection and localisation of gas clouds from a long distance. The optical measurement technique uses FTIR spectroscopy to identify the chemical composition.

always 100%. However, even from only a few metres away, it can be of any value depending on the direction the cloud travels in. Furthermore, local wind is constantly changing direction, especially in the corridors created by buildings, so the propagation direction cannot be predicted from the general wind direction. Given this volatility, a concentration value by itself provides little information as its position within the cloud is usually unknown. A sensor positioned only a few metres outside the propagation direction of the gas cloud will show a concentration which is several orders of magnitude lower than the mean concentration in the direct vicinity of the point of release. The detected value can be comparatively high for a leak of minor significance or remain very low even though there has been a major release.

Whenever a gas sensor raises an alarm, the operator in charge has the very tricky task of assessing the potential risk of the situation. On its own, gas sensor data is never enough if a momentous decision needs to be made as it is never clear whether a shutdown should be initiated, which is far too expensive if it turns out to be completely unnecessary, or if nothing should be done and thus risking a fatal accident.

Current monitoring concepts are flawed by the very principle of gas sensors: they only work properly if they are right in the middle of where the gas is. But as the exact origin of the gas release is unknow, manufacturers are at a loss. Closeness to the action is difficult to achieve and sniffing devices removed from the point of release cannot provide exact information. Moreover, the use of mobile gas measurement units is often limited to emergency situations. So, perhaps it might be wiser to take a step back and look at the gas cloud from further afield, in order to cover long stretches of a site. Indeed, such standoff techniques exist. Fenceline monitoring solutions and laser detection systems combine quantitative and spatial information and indicate the presence of a gas in certain areas of the site. These 2D perimeter approaches help to overcome the limitations of point sensors as they collect measurement data along a line of measurement points. Consequently, an even better solution could be to obtain a 3D picture of the entire site from a single vantage point.

Figure 4. The scanfeld sensor unit is a scanning and imaging infrared spectrometer that allows chemical identification and gas cloud mapping over a distance of up to several kilometres.

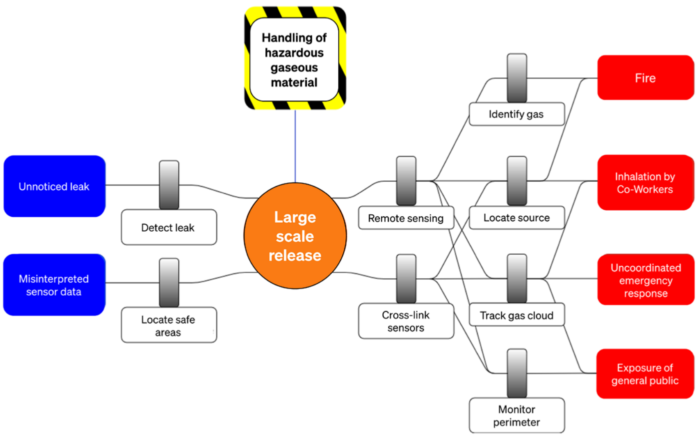

Figure 5. Risk assessment of a hazardous gas release. The remote monitoring approach prevents and mitigates effects (red boxes). It can detect a release before a hazardous situation occurs and can provide valuable information on the location of a hazardous cloud to support first response and disaster management.

Distance and overview

This is where the new measurement principle of remote sensing comes into play, which refers to the detection of gas clouds from a measurement point not inside the cloud, but from a distant point that can be several kilometres away. This principle is based on the spectroscopy of infrared radiation and Fourier-transform infrared spectroscopy (FTIR) is well established in laboratories as a technique to analyse the composition of a gas reliably and accurately. The difference between gas sensors and spectrometers is a bit like that between the human olfactory and visual senses. One can only smell a gas when already directly exposed to it, but it might be visible from far away. And if the compound has access to infrared vision, it can even be done in the dark of night – just like a rattle snake with its pit organ.

Transferring FTIR technology from the laboratory to industrial sites allows the detecton of gas leaks and the tracking of clouds. It thus provides early warnings and the necessary data for containment and mitigation. It visualises the gas cloud and also delivers the exact information of its chemical composition. Imaging FTIR spectroscopy works like a highly sophisticated camera.

Covering a whole industrial site from a distance has significant benefits. Most importantly, it will allow manufacturers to detect gas clouds even without any prior knowledge of their likely occurrence or position. It can also assess the entire gas cloud, locate its position and track its propagation.

Based on the analysis of existing infrared emissions of the surroundings the technique can be applied day and night in all surroundings and in every measurement direction. By enabling an unknown release to be detected, located and the released gas cloud mapped, it helps both to prevent and mitigate the consequences of hazardous events.

With the correct design, a remote monitoring system can be a most effective early warning solution to permanently monitor entire industrial sites.

Detect, assess, locate

A successful solution that warns the plant operator of an unknown gas leak needs to cover large areas of the industrial site, as well as provide a detailed spatial resolution. This is because many sites combine production areas, pipelines and loading stations in a very compact space. Here, elevated points such as the rooftops of high buildings will allow the necessary overview. The number of positions to provide a detailed overview of an entire site is driven by the design of the site. It is most important for a monitoring system to integrate a suitable number of measurement positions. The information of all measurement units must combine to provide a single visualisation that an operator can easily interpret. It should be displayed in the control room and fed directly to the overarching distributed control system (DCS) of the site.

The company's scanfeld provides such a solution for the fully automated permanent monitoring of entire industrial sites. It detects gas clouds at any point of the site in real time, analyses the gas composition and identifies the chemical compound among hundreds of target compounds including caustic gases such as ammonia or flammable ones like methane, ethylene or butadiene. As well as this, it visualises and tracks gas cloud in real time.

Designed in close contact with industry representatives to meet their needs, the scanfeld is a full solution that automatically monitors the site and is powerful enough to evaluate a huge stream of measurement data. Algorithms that identify the chemical composition of the gas cloud evaluate its spatial distribution and development over time to distinguish a real hazardous event from unavoidable fugitive emissions. The operator is warned on a scale of several alarm levels: the detection of a chemical compound only registers on the lowest level, but a persistent major hazardous gas release will immediately raise an alarm on the highest level. With no cross sensitivity and no need for calibration, the monitoring solution does not age, but rather it grows ever more competent, as it learns all typical states of 'normal' of a site and increases its capability to recognise hazardous incidents every day.

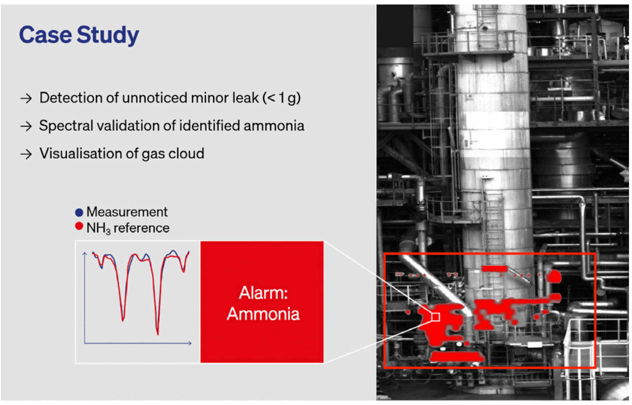

Figure 6. Measurement example: Detection of minor ammonia leak from a distance of 100 m. The area where the gas is identified is automatically displayed as a red overlay to a live video image of the scene. Spectral identification by comparison, using a proprietary library of hundreds of gaseous compounds.

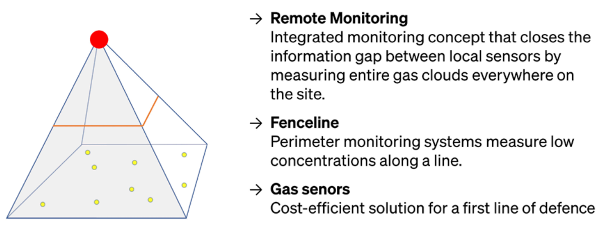

Figure 7. The integrative concept of early warning with remote monitoring. The approach includes existing technologies to provide the bigger picture.

Integrate approaches

To ensure the full awareness of any incidents on a site, the ideal safety approach should integrate any valuable technology, from established gas detectors to the company's scanfeld . Such an integrated approach is built like a solid pyramid.

On the first or basic level of the safety pyramid, several gas detectors are distributed on site, providing point measurement data and highly accurate concentration data for clearly defined locations. This can be achieved with common gas sensors or 'sniffing devices'. They can gather relevant information in the close vicinity of critical infrastructure, at points with elevated release potential or within confined spaces. They are the nose on the ground where you will most likely need it.

The second level of safety architecture is defined by 2D standoff techniques like fenceline monitoring solutions, laser detection systems or mobile gas measurement units that combine quantitative and spatial information and indicate the presence of a gas in certain areas of the site. This perimeter approach helps to overcome the limitations of a point sensor as it collects measurement data along a line of measurement points.

Distribution simulation software can further narrow down the area of interest in case of a known gas release. Any of these valuable measurement data can be incorporated in the 3D and holistic situation assessment provided by the scanfeld remote monitoring solution on the third level. Several scanfeld units, typically installed at elevated points of the site, constitute the peak of the safety pyramid.

Reduce risk and cost

Given the limited potential for passive and constructive protection improvement, as well as a steady increase in productivity, insurance companies and auditors are stipulating higher standards for early warning systems of hazardous gas releases. Companies feel that pressure and are starting to equip their sites with remote monitoring technology with success. Huge areas that were not monitored before can now be under 24/7 surveillance with a single remote sensor unit or even an integrated approach with several layers. Early gas leak detection will become a crucial point for the risk management of a site in the near future. Just as a rattle snake identifies risks with its pit organ, fertilizer manufacturers need a sixth sense. Remote monitoring is the answer. WF

References

1. MCGILIVRAY, A., and HARE, J., 'HSE Offshore Hydrocarbon Release 2001 – 2008' (2008).
2. FEITZ, A., et al.,'The Ginninderra CH_4 and CO_2 release experiment: An evaluation of gas detection and quantification techniques,' *International Journal of Greenhouse Gas Control*, Vol. 70, (2018), pp. 202 – 224, 10.1016/j.ijggc.2017.11.018.