Cumulative Exposure to Toxic Gases

As Health and Safety legislation tightens up world-wide, David Riddle, Business Development Manager at Crowcon Detection Instruments discusses the requirements of personal gas detectors in monitoring cumulative toxic gas exposure.

Toxic gases have an effect on the human body and brain cumulatively. It is possible that, after hourly, daily or weekly exposure to relatively low levels of gas, illness or injury may become apparent. It is vital, therefore to understand time based exposure of workers to toxic gases and not just rely on instantaneous alarms.

The definition of time weighted average varies across the world but for most companies concerned about exposure to toxic gases the terms of reference are similar to European and American requirements.

In Europe, the UK Health and Safety Executive publish EH40, which describes the new term WEL (workplace exposure limit). WELs are 'occupational exposure limits (OELs) set under COSHH*, in order to help protect the health of workers. WELs are concentrations of hazardous substances in the air, averaged over a specified period of time referred to as a time weighted average (TWA)'. It goes on to say that 'The first requirement of COSHH is to prevent exposure to substances hazardous to health…' These standards are legally enforceable and take into account European Commission Directive 80/ 1107/EEC.

In the UK, TWA is split into two areas: STEL (Short Term Exposure Limit) and LTEL (Long Term Exposure Limit). STEL is the maximum level of any given toxic gas, usually expressed in ppm (parts per million), that an average human being should be exposed to over 15 minutes. LTEL is the maximum ppm level over an 8 hour day or 40 hour working week.

In the USA, the Occupational Safety and Health Administration (OSHA) describe TWAs in Standard 29 CFR, 1910.1000. 'An employee's exposure to any substance…in any 8 hour work shift of a 40 hour work week, shall not exceed the 8-hour Time Weighted Average given for that substance...'

The requirements on exposure also vary from gas to gas and descriptions of what kind of exposure is allowable may be specific to a certain type of gas.

For instance, in the USA, it is noted that hydrogen sulfide has a maximum exposure level (known as the acceptable ceiling concentration) of 20ppm, but also, any exposure of 50ppm for 10 minutes, provided no other exposure has taken place, is enough to force the exposed workers to stop work for the day.

As you might expect, the LTEL for any toxic gas is a lower value than the STEL. For example, hydrogen sulphide has a STEL of 10ppm and an LTEL of 5ppm, reflecting the importance that both long and short term exposures are considered during any working period.

Human Senses

In the case of most commonly found toxic gases, the human olfactory system, buried in our noses, is capable of detecting levels well below the LTEL and STEL set around the world, so as soon as we enter a leisure centre with a swimming pool, we can smell the chlorine, even though the levels are fractions of parts per billion (ppb) in the air. Chlorine becomes toxic when we are exposed to 0.5ppm (500ppb) or more. Hydrogen sulphide can also be smelt at ppb levels and has the characteristic rotten eggs odour. At higher levels of exposure, hydrogen sulphide can disable your olfactory gland leaving you with the impression that the gas is absent.

In the case of some toxic gases, we are not able to smell them at all. The most commonly found toxic gas in the world is carbon monoxide, which is produced when incomplete combustion of hydrocarbons, natural gas, petroleum or any carbon based substance, including cigarettes is burned. CO does not have an odour although many people mistake the smell of other particulates in the air for the smell of carbon monoxide, but when natural gas is burnt, the particulates are not found and the smell is absent.

This situation can best be summarized as follows: just because you can smell gas, does not mean to say it is at a dangerous level and if you cannot smell gas, it does not mean that there is none.

Given all of this information, sometimes conflicting with what our experience may tell us while working, it is even more important that exposure levels are observed

Duty Of Care

In most countries, the TWA limits are set down by the relevant government health and safety body (in the UK it is the HSE, in the US it is OSHA) and is enforceable by law, based on the requirement that employers have a duty of care and protection for their employees. In fact, in many countries, an instantaneous alarm level is not stipulated and was essentially provided by manufacturers of gas detection instruments from decades past, when instrumentation was not capable of calculating exposure over time.

Best practice dictates that it is essential to have TWA alarms. Instantaneous alarms are a useful additional feature but no replacement for TWA.

This approach is meant to protect workers from exposure by ensuring that portable gas detectors go into alarm at the lowest required TWA level. When a release of hydrogen sulphide or sulphur dioxide occurs at a crude oil refinery, it is important that workers evacuate as quickly as possible when they hear their personal gas detectors go into alarm. In some cases, workers will be exposed to quite high levels of gas, while they extricate themselves from their work area, climb down enclosed ladders and get to a safe area. Sites may have fenced boundaries and be a few kilometers or miles long. If the wind is blowing unfavourably, this could have the effect of spreading a toxic gas cloud across a site, giving workers a longer dose while they are attempting to evacuate.

Once out of the danger zone, personal gas detectors will reflect this by showing low readings of gas, beneath the TWA levels and their alarms may be silenced. The questions remain; how much gas is left on site and for how long will workers be allowed to work at this (safe) level? The calculations done internally by personal gas detectors allow site managers and supervisors to be confident that the levels of cumulative exposure are being monitored over the whole working day.

Some regulatory bodies would expect that, unless TWA alarms can be provided by a personal monitor, any instantaneous alarm activation would trigger an action plan whereby the worker should be monitored for cumulative exposure and an investigation of the cause of the gas release is undertaken . Also, persistent instantaneous alarms should mean that managers examine their processes to ensure that exposure to toxic gas is reduced. Risk assessment law is not fully prescriptive in this way, but there is an expectation that a duty of care to workers is employed.

The problem with just reacting to the instantaneous alarm & ignoring any longer term exposure levels is that, with such low TWA levels, workers can be exposed to cumulative levels of gas (whereby they should stop work) without them or their managers knowledge. TWA limits are ever decreasing in law as health and safety legislation tightens up world-wide and shareholders are more and more sensitive to potential litigation.

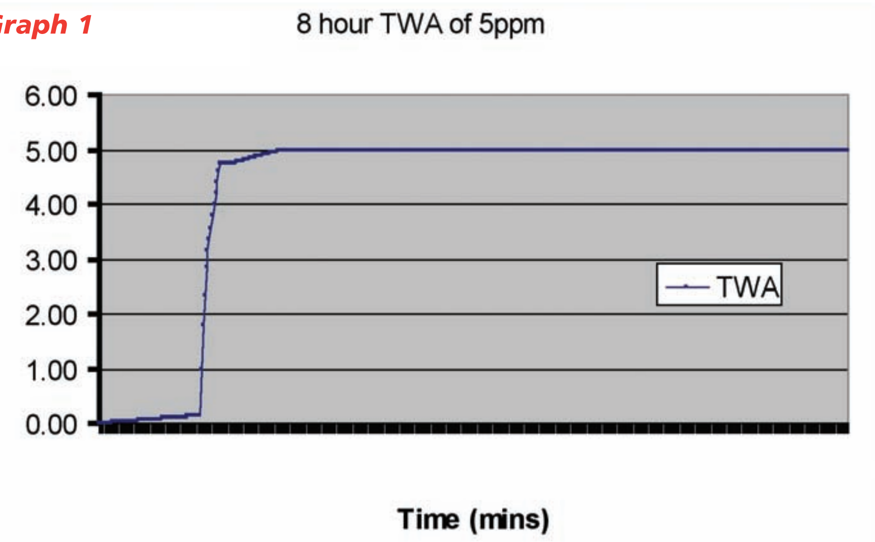
Given that Time Weighted Average limits and standards assume an 8 hour shift and 40 hour week, it is important to consider that any working time over these levels should add exposure by assuming that it took place within an 8 hour shift, hence a worker on a 12 hour shift would not be allowed the same background level of gas as one on an 8 hour pattern. Most personal gas detectors take this into account and will continue to calculate cumulative exposure using 480 minutes rather than 720 minutes.

To provide a specific example of where hydrogen sulphide exposure could prove problematic, we need to look at US, UK and other European regulations and set limits.

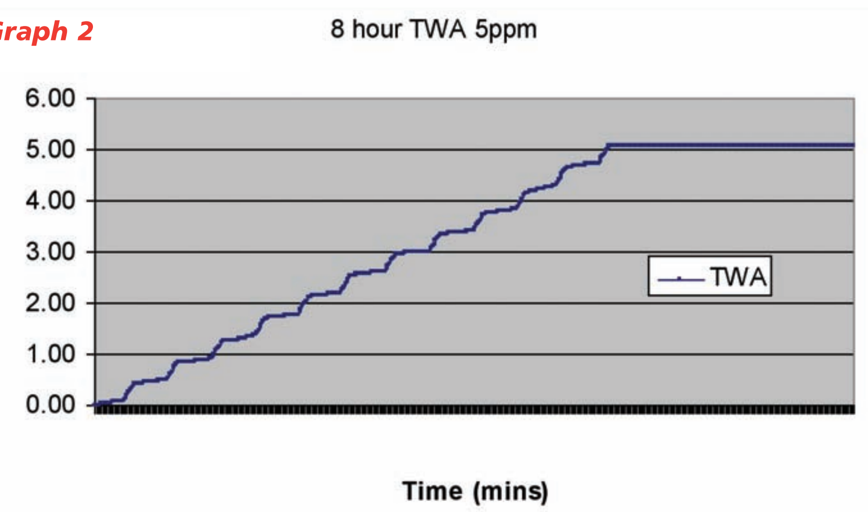
In graph 1, a low level of exposure, well below any alarm or exposure limit is experienced. The calculated TWA level slowly but steadily rises. After around 1 hour working, there is a leak of gas and the instantaneous alarm is activated. The TWA exposure is seriously impacted but the worker evacuates and readings return to zero. The question should be asked now whether the worker may continue to work in the previous low background of toxic gas. When the worker returns, once again there is low level exposure and this starts to affect the TWA level. After a further 3/4 hour, the TWA alarm level is passed and the worker should leave site even though there is only a low level of background gas, because the overall exposure level has been reached.

In graph 2, again the background level of gas is low, around 1-2 ppm. Throughout the working day, a series of small releases of gas occur, with the result that the worker must enter and exit the work area several times during the day. The personal gas

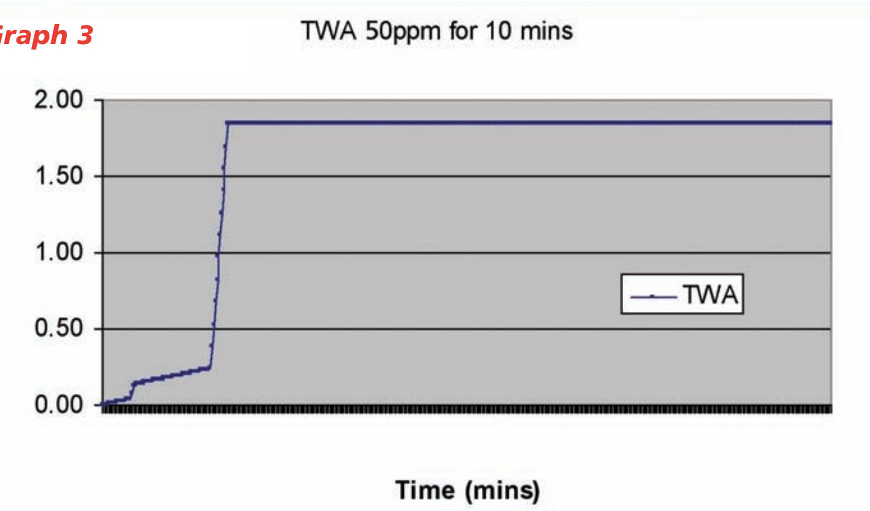
Graph 1



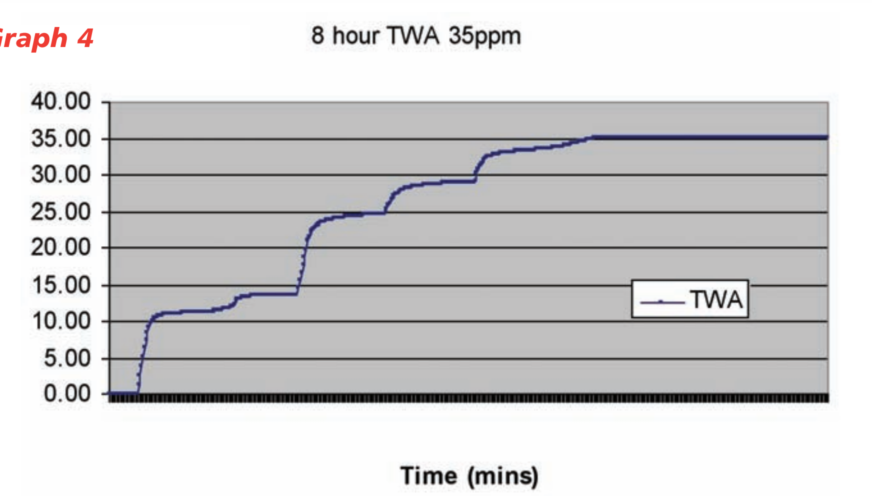
Graph 2



Graph 3



Graph 4



detector will provide an instantaneous alarm on each of these occasions. After around 5 hours of the shift, the short term exposures to gas mean that the TWA level is passed and the worker should leave site, even though once again, the ambient level of H2S is low at the time.

In graph 3, reflecting the US standard, there is an early exposure, where workers evacuated the area but then returned when gas levels reduced. Shortly afterwards a large release of gas meant that the worker was exposed to higher levels of gas for 10 minutes before clearing the area. This exceeds the daily allowable rate and the worker should leave site and again H2S levels have reduced to low level.

Graph 4 shows a series of doses of carbon monoxide, which is commonplace in the steel industry. Again the TWA set-up of the gas detector would ensure overall exposure levels are obtainable and alarms would activate during the latter part of the day.

What is also noticeable from these graphs is that, even when gas levels are well below instantaneous or TWA alarm levels, these small concentrations still contribute to overall exposure, so even if there is a low background of gas, this may still activate the TWA alarm if there were previous high levels causing temporary evacuation.

Most modern gas detectors provide this TWA alarm functionality. Many manufacturers set the alarm tone to be distinctive from the instantaneous alarm, specifically because it shows that, across the day, the worker has been over-exposed.

If there is an incident on-site and managers are aware that workers have been exposed, most personal gas detectors are equipped with on-board data, event and even threshold logging. This enables data to be downloaded to a PC and analysed, providing information for any incident audit or investigation as well as confirming exposure over time.

Logging of Exposure

If there has been an incident, which requires investigation, regulatory bodies will ask for a record of gas exposure and evidence of an action plan. Instruments that record the data can provide this in easily accessible formats.

Data logging

Data logging is where the peak reading of gas over a pre-set period is recorded. Usually, this period is set at 1 minute at the factory and so the log will record the highest (or lowest in the case of oxygen readings) concentration of gas the instrument/worker was exposed to during that minute. Each minute, the time, date and reading are recorded, providing an entire picture of exposure levels across every working day. If an incident occurs, it is possible to download a week's worth of data to provide an audit trail and a complete picture of exposure to gas. Most gas detectors have enough memory capacity to store many weeks of data, assuming a 40 hour working week and 1 minute records.

Event Logging

Event logging is a very useful form of data logging. It only tracks important events where every notable activity of a personal monitor is recorded. These should always include switch-on, switch-off, zeroing, calibration, bump testing, instantaneous alarm and, of course, TWA alarm, short and long term. Each activity is recorded with a time/date stamp and can be recalled via PC interface. Most personal gas monitors will provide users with enough events to record many weeks or months of notable activity. This can be important where monitors are issued to specific individuals and supervisors need proof that instruments are regularly bump tested, calibrated or even switched on.

Threshold Logging

Threshold logging is often viewed as more concise and user friendly. Managers or supervisors may set a threshold, over (or under in the case of oxygen) which the personal monitor records data. It may be of less interest that there is a negligible or non-existing background level of gas. All the data shown on the downloaded threshold log is over the pre-set level, so it is not necessary to wade through hours of zero or low level gas readings in order to analyse specific incident data.

Audit Trail and Incident Report

In any case where employees have been exposed to gas, the site safety department may require an audit or incident report. If there is an injury or fatality, or during a routine visit government department inspectors may also call for an audit trail. Both TWA alarms and data logging may provide data to ensure information provided is complete and accurate.

Cumulative exposure to toxic gas should be monitored and recorded where necessary to enable workers to be properly protected.

**COSHH – Control of Substances Hazardous to Health*

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