Where there is potential exposure to Hydrogen Sulfide, a monitoring strategy is recommended to ensure exposures are kept below acceptable levels and standards and that appropriate action is taken when there are excursions above these levels. Either traditional IH monitoring methods or electronic instruments can be used for this purpose.

**ABSTRACT**

In order to better protect workers from exposure to Hydrogen Sulfide (H$_2$S), ACGIH modified the Threshold Limit Value (TLV) for this chemical in 2010. This white paper presents information on the health effects of H$_2$S exposure, how it has been monitored in the past, and technology available to monitor H$_2$S in the workplace today to meet these new TLV guidelines. It also suggests a way to incorporate modern H$_2$S monitoring technology into an industrial hygiene and safety program.

**BACKGROUND**

Recently, the American Conference of Governmental Industrial Hygienists (ACGIH) changed their recommended threshold limit values (TLVs) for airborne hydrogen sulfide (H$_2$S) exposure. From 1976 thru 2009, the ACGIH 8-hour time weighted average TLV (TLV-TWA) was 10 parts per million (ppm), and the 15-minute short-term exposure limit TLV (TLV-STEL) was 15 ppm. In 2010 the ACGIH adopted a TLV-TWA of 1 ppm, and a TLV-STEL of 5 ppm for H$_2$S. In the United States the ACGIH TLV is not a regulatory limit, however these guidelines are developed from scientific data gathered by ACGIH over several years on the health effects of H$_2$S exposure and represent exposures that “all workers may be repeatedly exposed, day after day, over a working lifetime, without adverse health effects”.

ACGIH is a globally recognized authority on establishing exposure limits for chemical agents including toxic gases, and the recent changes in its H$_2$S TLV-TWA and TLV-STEL followed a 5-year review period. During that time industry representatives had the opportunity to express any concerns and recommendations they might have. Now that ACGIH has made these changes official, companies that have employees potentially exposed to H$_2$S should consider this information in their industrial hygiene and safety programs. Since these new TLV values are established by ACGIH to protect the health of workers and this is the goal of all industrial hygiene and safety programs, use of this new information needs to be considered when planning industrial hygiene monitoring for employee H$_2$S exposures.

Still, there is the question of whether or not these new ACGIH TLV guidelines are practical in terms of current monitoring and detection technology. While the ACGIH recommendations are expressed in terms of an 8-hour TWA and 15-minute STEL, many companies tend to set action points in their safety and hygiene procedures based on instantaneous exposures or one minute average ceiling$^1$ limits as read from an electronic sensor in a personal monitoring instrument. This begs the question: “Are electrochemical sensors available that can accurately detect an H$_2$S concentration at some ceiling limit value that makes sense in terms of the ACGIH-specified TWA and STEL, without a lot of false alarms?”

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$^1$ Ceiling: The concentration that should not be exceeded during any part of the working exposure. If instantaneous measurements are not available, sampling should be conducted for the minimum period of time (typically, one minute) sufficient to detect exposure at or above the ceiling value.
HEALTH EFFECTS OF H₂S EXPOSURE

The odor threshold for H₂S is as low as 0.008 ppm, olfactory fatigue may occur at 100 ppm, and paralysis of the olfactory nerve has been reported at 150 ppm (1). There are also other human health effects of hydrogen sulfide that have need to be communicated to people as outlined in Table 1. These effects have been used to establish the current exposure limits.

Based on the health effects of H₂S, an Immediately Dangerous to Life and Health (IDLH) value of 100 ppm was updated and published by NIOSH (National Institute of Occupational Safety and Health) in 1995. Although most people can smell very low concentrations of H₂S (Table 1), it is dangerous to assume that the odor provides adequate warning. At concentrations above the IDLH level, a person’s sense of smell is quickly deadened. This health information has given rise to the following guidelines where worker exposure to H₂S is possible:

- Use detection equipment when working in an area where there is a possibility of H₂S, especially in enclosed or below grade locations (holes, trenches, reserve pits, etc.).
- Maintain and calibrate detection equipment per manufacturer’s specifications.
- Do not enter an H₂S area without authorization, proper training, and suitable NIOSH approved H₂S filter and Air Purifying Respirator (APR) mask, or a Self-Contained Breathing Apparatus (SCBA).
- Employees working in H₂S areas are required to be properly “fit tested” with their APR or SCBA mask.
- In IDLH atmospheres a standby person(s) with SCBA must be available for rescue purposes. Never attempt to rescue an H₂S victim without a SCBA.
- All H₂S exposure victims should be treated by a physician before returning to work.
- In the event of an H₂S emergency, all personnel should follow the site emergency plan.
- H₂S areas, facilities, pipelines, and/or flow lines should be properly identified with signage.

There are many places where H₂S gas can be generated during chemical processes (e.g., petroleum industry; leather tanning; viscose rayon production; pulp and paper mills), or simply due to decomposition of organic matter. The latter can occur in locations such as sewers and septic systems, sewage treatment plants, stagnant sumps, etc.

TABLE 1 – HUMAN HEALTH EFFECTS OF HYDROGEN SULFIDE AT VARIOUS CONCENTRATIONS [3]

<table>
<thead>
<tr>
<th>ppm</th>
<th>Signs and symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.008</td>
<td>Odor threshold</td>
</tr>
<tr>
<td>2</td>
<td>Bronchial constriction in asthmatic individuals</td>
</tr>
<tr>
<td>4</td>
<td>Increased eye complaints</td>
</tr>
<tr>
<td>5 or 10</td>
<td>Increased blood lactate concentration</td>
</tr>
<tr>
<td>4-21</td>
<td>Decreased oxygen uptake</td>
</tr>
<tr>
<td>20</td>
<td>Eye irritation</td>
</tr>
<tr>
<td>&gt;100</td>
<td>Fatigue, loss of appetite, headache, irritability, poor memory, dizziness</td>
</tr>
<tr>
<td>&gt;402</td>
<td>Olfactory paralysis</td>
</tr>
<tr>
<td>≥502</td>
<td>Respiratory distress</td>
</tr>
<tr>
<td></td>
<td>Death</td>
</tr>
</tbody>
</table>

CURRENT MONITORING PRACTICES

H₂S detection and monitoring practices vary by industry and the location of company operations (state, province, country, etc.). In one way or another, many types of gas monitoring equipment have the capability to continuously collect gas concentration data from a fixed location in a monitored area. In some cases data logging is a built-in function of a monitoring instrument. In other cases, the detector instrumentation can be connected to a PC or networked computer that runs software to collect and analyze the data. Historically, few companies have actually built an archive of such data, which could allow them to determine their employee TWA and STEL exposures in a quantitative manner similar to the literature ACIGH used in establishing its current H₂S TWA and STEL values.

ADOPTING THE LATEST DETECTION TECHNOLOGY

So what instrumentation is available to support and monitor for these new guidelines? The prevailing methods of detection and monitoring in the workplace are colorimetric detector tubes and personal monitoring instrumentation that uses electrochemical sensors. It turns out there are commercially available products for both methods that have the sensitivity and accuracy needed to support the new ACIGH H₂S TLV-TWA and TLV-STEL guidelines. However, an electrochemical sensor in a personal monitoring instrument is the most practical because it responds within seconds to a gas exposure. For example,
the Draeger Model X-am 5000 Gas Detector equipped with an XXS H\textsubscript{2}S LC sensor has a response time of 15 seconds or less. It also has a lower detection limit (sensitivity) of 0.4ppm, with 0.1ppm resolution (smallest detectable change), and an accuracy of ±5% over its calibrated range of 0-100ppm. Other features include a built-in data logging function, and intrinsically safe design for use in hazardous duty areas where there may be a hazardous or explosive atmosphere.

There are various ways such an instrument could be used in an industrial hygiene and safety program to monitor H\textsubscript{2}S and meet ACIGH guidelines. With an accuracy of ±0.05ppm at 1ppm (±5%) the X-am 5000 is more than adequate to meet the requirement of a reliable alarm and monitoring system. It has a low probability of false alarm results from the small temperature drift of the Draeger XXS H\textsubscript{2}S LC sensor (less than 0.1ppm for the zero reading), and high selectivity for H\textsubscript{2}S in the presence of interfering gases such as sulfur dioxide, nitrogen dioxide and hydrocarbons.

**IMPLEMENTATION ISSUES**

When monitoring equipment is selected for H\textsubscript{2}S there are several issues that need to be considered. How do I monitor the 8 hour TWA and STEL exposure? In addition to periodic employee exposure monitoring, do I have employees wear gas detectors with alarms to warn of peak concentrations? If yes, what level do I set the alarm – 1PPM, 5PPM, 10 PPM? Do I also need areas monitoring to detect the presence of H\textsubscript{2}S in critical areas to warn employees of its presence?

In order to provide maximum protection, it would be best to have an electronic instrument that could measure and store both the 1 PPM TWA and 5PPM STEL H\textsubscript{2}S levels and provide and alarm when concentrations reached 5 PPM. This instrument would have the following characteristics: it would measure both short term and time weighted average exposures; it would store the results for review after the monitoring was complete; it would have an alarm to warn the use of high H\textsubscript{2}S levels; and it would be easy to operate.

The other consideration is for stationary measurement instruments associated with specific processes that would warn workers when concentrations exceeded the new STEL of 5 PPM. This would allow exposure avoidance – particularly in enclosed areas where H\textsubscript{2}S may accumulate. For this application, an instrument with the following characteristics should be selected: it could be set to measure multiple gases; it would have an alarm to warn people of high concentrations; it would be rugged so it would stand up well in oil and gas environments and there would be adequate instructions/technical support for the monitoring equipment.

**DRAEGER PORTABLE/PERSOAL AND STATIONARY AREA MONITORING EQUIPMENT**

The X-am 5000 portable monitoring instrument is an ideal solution for users who want to be able to accurately and reliably measure H\textsubscript{2}S exposure levels. It provides a noticeable visual, audible and vibration alarm notification to alert the user once exposed to a dangerous level of H\textsubscript{2}S gas. The unit offers an easy-to-use intuitive interface and displays all alarm set-points A1 and A2 as well as TWA and STEL measurements in succession. The STEL alarm cannot be cancelled once reached as it is the recommendation that the user immediately evacuate that dangerous environment. The instrument also features data logging which records the entire history of the monitor for complete analytical and safety uses.

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http://www.nap.edu/catalog/12978.html

2) NIOSH Documentation for Immediately Dangerous To Life or Health Concentrations (IDLHs)

The H$_2$S sensor within the X-am 5000 has an expected life greater than five years providing reliable safe performance in demanding conditions and there is even the flexibility of selecting either a Low Concentration (LC) or High Concentration (HC) H$_2$S sensor choice for instrument based upon application needs.

Draeger's X-zone 5000 transforms the portable X-am 5000 instrument into a powerful area monitoring solution for H$_2$S as well. This patented combination is transportable, rugged and waterproof, extending mobile gas detection to a unique system with many flexible application. X-zone units can be connected wirelessly to establish continual perimeter or fenceline monitoring of H$_2$S and other potential hazardous gases. The X-zone features an illuminated LED ring, which provides a bright green visual indication that the air is free of toxic and combustible gases. When gas hazards are detected, the LED ring changes colors from green to red, providing a visual warning that a hazardous gas such as H$_2$S is present. In addition, the X-zone emits an extremely loud and audible 360 degree sweeping amplified evacuation alarm.

By using the X-am 5000’s built-in data logger with an optional USB adapter and cable, it can output exposure data to a PC for analysis and reporting. This documentation is accomplished by running Draeger’s Gas Vision® software on the PC (Figure 2). It quickly and easily determines TWA and STEL exposures, creates graphs, spreadsheets, and reports from this data, and manages all the stored exposure data files. It’s easy to search previous reports by date, gas measured, or person monitored and get only the information you need, including serial numbers and sensor calibration dates for the monitors used.

CONCLUSIONS

From the standpoint of available technology, there is no reason not to adopt the 2010 ACIGH guidelines for monitoring H$_2$S exposure. Adopting the new guidelines and equipping workers with a personal/portable H$_2$S meter such as the Draeger X-am 5000 will give them greater protection from Hydrogen Sulfide exposure and improved methods for companies to determine and document exposures.