Trailwalk Holdings Ltd.
Maintenance Consulting

H2S Awareness

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Welcome to the Trailwalk Training Series. Today, we will be talking about the hazards associated with Hydrogen Sulfide (H_2S) and how to protect yourself from its deadly effects. The course is divided into 6 sections. Watch the video for each section and then complete a quiz. After the last section there is a final exam to test your knowledge about H2S.

H_2S is a colorless gas that is created naturally as bacteria breaks down organic material and waste from humans and animals. It occurs primarily in sewage and oil, but may also occur anywhere there is lots of biodegradation, such as swamps or manure stockpiles.

H_2S is denser than air. This causes a major hazard, as it will settle in lower areas, displacing air and cutting off oxygen supply. H2S is also soluble in water, oil, and gas. For this reason, confined spaces, holes, trenches, and poorly-ventilated areas are more likely to contain H2S.

H_2S is also very flammable and an explosive hazard. It's important, when working in areas where H_2S is present, that you take care not to use any electric, gas, or other tools that may cause a spark.

H_2S is toxic to the body and can kill in minutes, depending on the conditions.

Hydrogen Sulfide is most commonly found in oil operations, but many incidents occur with waste water treatment plants, and sewers. Exposure to H_2S may also occur in swamps or agricultural silos and manure pits, it is created by the bacterial breakdown of organic materials. Other jobs where there may be risk of exposure are pulp, paper, and food processing, hot asphalt paving, mining, and other textile industries.

Helpful Terms

Parts per million (ppm): A means to measure the concentration of H_2S. Parts per million indicates how many volume-based units out of a million the substance in question makes up.

Both OEL and TWA refer to the maximum exposure to H2S in a given time period.
Occupational Exposure limit, or **OEL is** the maximum amount of exposure that workers can have over a designated amount of time, usually measured 8 hours.
TWA: (Time Weighted Average) is a term commonly used to measure the concentration of H2S
TWA means:
- an average value of exposure over the course of an 8 hour work shift.
Acceptable Ceiling Concentration: The maximum amount of a substance that a worker can be exposed to during a regular work day.

Competent Person: One who is capable of recognizing H_2S hazards and has the authority to take immediate corrective measures to mitigate or eliminate them. A competent person should know how to test for H_2S, what to do in case of exposure, and how to respond to emergency situations.

Qualified Person: A qualified person has a degree, certificate, professional standing, extensive knowledge, training, and experience with whatever subject is being referenced. They will have the ability to identify, resolve, and solve issues in the particular field or work being performed.

PRACTICE 22: Hazardous Spaces

Purpose

To instruct Employees on how to safely enter a hazardous space.

Definitions

Hazardous Space — an enclosed or partially enclosed space that meets one (1) of the following criteria:

- is not designed or intended for regular human occupancy;
- has restricted access or exit; and
- is or may become hazardous to a person entering it because of its design, construction, location, atmosphere, or the materials or substances in it or other conditions.

Examples of hazardous spaces could include, but are not limited to: underground control chambers, pumping stations, dry or wet wells, wastewater treatment facilities, and rotating biological contactors (RBCs)

Physical Agent —relates to threshold limit values for occupational exposure, means an agent of acoustic, electromagnetic, ergonomic, mechanical or thermal nature.

TLVs and BEIs — the latest version of the publication of the American Conference of Governmental Industrial Hygienists of threshold limit values and biological exposure indices.

Threshold Limit Values — the threshold limit values established by the TLVs and BEIs that represent:

- chemical substances, and the airborne concentrations of chemical substances and conditions under which it is believed that nearly all healthy workers may be repeatedly exposed, day after day, over a working lifetime, without adverse health effects;
- for physical agents, the levels of exposure and conditions under which it is believed that nearly all healthy workers may be repeatedly exposed, day after day, without adverse health effects.

Roles and Responsibilities

- **Responsibilities of the Supervisors**
  - Ensure the space is labeled and identified to Employees as a hazardous space.
  - Develop SOPs for Employees entering a hazardous space which outlines the safety precautions noted within this practice.

- **Responsibilities of the Employees**
  - Use gas monitors when entering hazardous spaces.
  - Inform their Supervisor of any issues encountered when entering hazardous spaces.
  - Make recommendations on how to improve safety measures within hazardous spaces.

Practices/ Procedures

HAZARDOUS SPACES PROCEDURE	DESCRIPTION
General Safety Measures	• Supervisor must determine if a space is considered hazardous prior to work being conducted. • If the space is considered to be hazardous then it must be labeled a hazardous space. • Underground control chambers must be tested at 3 levels. The air quality can be measured using a gas meter equipped with an aspirated pump and tubing. Test the air for 2 minutes plus 2 seconds per foot of tubing. Test at 3 depths: top, middle and bottom of chamber and record readings on the log sheet. • An SOP will be developed to follow while performing work in that particular hazardous space. • Follow Gas Monitoring Procedure, Section 27.
Entering a Hazardous Space	Employees must be equipped with personal gas monitor before entering a hazardous space.

Water Utilities commonly use a H_2S TWA level of 3 PPM and an acceptable ceiling limit of 5 PPM. Once concentration levels of H2S exceed 3 PPM all workers should leave the area immediately. Make sure that all workers in the area are informed of the danger, and that everyone makes it out of the contaminated area safely.

H_2S is dangerous. At levels as low as 5 parts per million, it begins to affect the body negatively. At higher concentrations, it can cause death almost instantaneously. To make matters worse, H_2S is completely invisible to us. However, with the proper training, precautions, and equipment, you can keep yourself from being exposed to this dangerous gas.
Once the H_2S concentration reaches 100 ppm, it is considered immediately dangerous to life and health. At this level, your ability to smell the gas disappears, and anyone exposed will begin to feel drowsy and have altered breathing. Workers need to evacuate the contaminated area immediately and get fresh air.

H2S Exposure

The most common and most dangerous route of exposure to H_2S is through inhalation. H_2S does not disperse in the air. As a result, it often condenses, allowing for the concentration to spike rapidly in comparison to other atmospheric gases. Because it is heavier than air, these high concentrations are commonly found in confined spaces, trenches, or other low-lying ground. However, this isn't always the case.
Hydrogen Sulfide will affect you in multiple ways. Some examples of these effects are the saturation your red blood cells and prevention of oxygen from being dispersed throughout the body. The main targets of H_2S are the nervous system and the respiratory system.

After being attached to blood cells, H_2S is transported to the brain. From there, it begins to shut down the nervous system, leading to fatigue and dizziness. H_2S will also attack the respiratory system and, at high enough concentrations, completely shut it down. This quickly leads to unconsciousness and death.

H_2S is also a known eye irritant and may cause lasting damage after exposure. At concentrations as low as 50 ppm, it can cause acute conjunctivitis. Do not wear contacts when working with H_2S.

Effects vs Concentrations

The danger that H_2S presents depends on the concentration of the gas. If the concentration is low, it will only cause discomfort, but as the concentration rises, the effects of the gas can cause severe damage, unconsciousness, and eventually death.

The body can get rid of H_2S naturally, and most people who are exposed make a full recovery, although some have complained of chronic issues after exposure. The primary time to be concerned is when there are high levels of exposure within a short period of time.

Did you know?

H_2S is actually a natural bi-product of certain bacteria found in the human body. Because of this, the body is adept at getting rid of H_2S naturally when exposed to small doses. However, it can be quickly overwhelmed when exposed to highly concentrated doses.

Symptoms vary by concentration. At 2 ppm, prolonged exposure may result in nausea, watery eyes, headaches, and loss of sleep. When concentrations reach 20 ppm, symptoms escalate to dizziness and fatigue, loss of appetite, irritability, and poor memory.
When concentrations reach 50 ppm, those exposed will present slight conjunctivitis or “gas eye” and respiratory tract irritation after about an hour. When concentrations are at 100 ppm, these symptoms will escalate to eye irritation, altered breathing, coughing, and throat irritation. At this point, you will lose the ability to smell the gas.

At concentrations exceeding 200 ppm, exposed workers will suffer marked conjunctivitis. Damage to the lungs that results from corrosive gaseous properties can result in pulmonary edema (lungs filling with fluid). As concentrations reach 500 ppm, workers will collapse within 5 minutes of exposure, suffer severe damage to the eyes, and die in less than an hour.
Once the concentration exceeds 700 ppm, exposed workers will lose consciousness in one to two breaths. Death will occur within minutes. Concentrations exceeding 1000 ppm will result in near-instant death.

What are First Aid Measures for Hydrogen Sulfide?

Inhalation: Take precautions to prevent a fire by removing any sources of ignition. Take precautions to ensure your own safety before attempting rescue by wearing the appropriate protective equipment etc. Move victim to fresh air. Keep at rest in a position comfortable for breathing. If breathing is difficult, trained personnel should administer emergency oxygen. DO NOT allow victim to move about unnecessarily. Symptoms of pulmonary edema may be delayed. If breathing has stopped, trained personnel should begin artificial respiration (AR). If the heart has stopped, trained personnel should start cardiopulmonary resuscitation (CPR) or automated external defibrillation (AED). Avoid mouth-to-mouth contact by using mouth guards or shields. Immediately call a Poison Centre or doctor. Treatment is urgently required. Transport to a hospital. NOTE: Victims may pose a threat to responders due to the release of hydrogen sulfide from their clothing, skin, and exhaled air.
Skin Contact: Liquefied gas: quickly remove victim from source of contamination. DO NOT attempt to rewarm the affected area on site. DO NOT rub area or apply direct heat. Gently remove clothing or jewelry that may restrict circulation. Carefully cut around clothing that sticks to the skin and remove the rest of the garment. Loosely cover the affected area with a sterile dressing. DO NOT allow victim to drink alcohol or smoke. Immediately call a Poison Centre or doctor. Treatment is urgently required. Transport to a hospital. Double bag, seal, label and leave contaminated clothing, shoes and leather goods at the scene for safe disposal.
Eye Contact: Gas: immediately flush the contaminated eye(s) with lukewarm, gently flowing water for 15-20 minutes, while holding the eyelid(s) open. Liquefied gas: immediately and briefly flush with lukewarm, gently flowing water. DO NOT attempt to rewarm. Cover both eyes with a sterile dressing. DO NOT allow victim to drink alcohol or smoke. Immediately call a Poison Centre or doctor. Treatment is urgently required. Transport to a hospital.
Ingestion: Not applicable (gas).
First Aid Comments: Some of the first aid procedures recommended here require advanced first aid training.

H2S Monitoring

One of the most dangerous aspects of H_2S is that it is almost entirely undetectable by the human senses. At lower concentrations, it lets off a putrid odor that smells like rotten eggs. However, at higher levels, 50 ppm and above, H_2S will be completely odorless. **It is vitally important that you never rely on your sense of smell to detect H_2S.**

Where Is H_2S Found?
Because H_2S is the bi-product of bacteria breaking down organic materials it is often present in sewage. It is also commonly found in manure pits during agricultural operations and marshes where lots of organic material is breaking down. The most common occupational source, however, is crude oil operations.

H2S is completely soluble in water, oil, and gas. When any of these liquids has dissolved H2S, and is disturbed, it will release the toxic gas into the air. For this reason it is vital that H2S in the air is continually monitored in confined spaces, oil operations, and wastewater treatment and sewage operations.
H_2S will accumulate at the lowest points possible. Air testing and monitoring should be performed anytime work is being done in low-lying areas such as trenches or pits, that are close to areas that might have H_2S gas, including marshes, water treatment plants, or petroleum operations.
H_2S is among the most common gasses found in confined spaces, and it is also one of the most toxic. When H_2S is in a confined space, it will displace the oxygen, creating an extremely dangerous atmosphere for unsuspecting victims.

Monitors

Some worksites have monitors and alerts set up to detect gases or leaks in certain areas. Anytime a gas leak is detected, workers in that area should be notified and cleared in case the accumulation of H_2S leads to dangerous concentration levels.
Many worksites that deal with H_2S or run the risk of exposure to H_2S will equip their workers with personal gas monitors. These monitors are small and can be clipped to clothes and worn by workers. With monitors, they can monitor H_2S and be alerted in case it reaches dangerous levels.

Workers with personal air monitors need to be trained on how to use them, where on their bodies to fasten them, and how to interpret the readings. Workers ought to be thoroughly instructed on what levels are safe and what to do when exposed to unsafe levels.

Personal air monitors need to be calibrated on a regular basis. Be sure to check the owner's manual for instructions regarding when and how to do this. Monitors that have not been calibrated within the designated time frames are not reliable and should not be used in the field.

As best practices go, you should bump test (field test) and check calibrations on your monitors regularly in order to ensure that the alarms, both visual and audible, are working and responding at the correct levels. How often is "regularly?" A bump test or calibration check of portable gas monitors should be conducted before each day's use in accordance with the manufacturer's instructions.

If the instrument fails the bump test or calibration check, you must perform a full calibration on it before use. If it fails the full calibration test, it must be immediately removed from service. Always follow the manufacturer's instructions regarding these tests and their frequency. All tests should be done with a certified (and up-to-date) traceable gas and in an environment that imitates normal working conditions (temperature, humidity, atmospheric pressure, etc.)

Did you know?

A daily bump test can save your life…
On a given day, it is estimated that 1 in 2,500 untested gas monitors will fail to respond to a dangerous concentration of gas. A bump test, also called a field test, is a functionality test of sensors and alarms. You should receive training on how to properly administer this test. A bump test is performed by exposing the monitor/sensors to a known concentration of the target gases, then verifying that the display has correctly reported the correct concentration and that the appropriate alarms have sounded.

SECTION 27: GAS MONITORING

27.01 Purpose

The intent of this procedure is to ensure the health and safety of Halifax Water Employees at all times when using gas monitors.

27.02 Scope

This procedure shall apply to all confined spaces, hazardous spaces, and facilities under the care and control of Halifax Water including all contracted services.

27.03 Definitions

"ACGIH" — is the American Conference of Governmental Industrial Hygienists.

"Clean Respirable Air" — when used to describe the atmosphere inside a Confined Space, means an atmosphere which is equivalent to clean, outdoor air and which contains:

- about 20.9% oxygen by volume;
- no measurable flammable gas or vapour as determined using a calibrated gas measuring instrument; and
- no air contaminant in concentrations exceeding either 10% of its applicable threshold limit value as published by the ACGIH.

"Competent Person" — means a person who:

- is qualified because of that person's knowledge, training and experience to do the assigned work in a manner that will ensure the health and safety of every person in the workplace, and
- is knowledgeable about the provisions of the Act and regulations that apply to the assigned work, and about potential or actual danger to health or safety associated with the assigned work.

"Confined Space" — an enclosed or partially enclosed space that:

- is not designed or intended for regular human occupancy;
- has restricted access or exit; and
- is or may become hazardous** to a person entering it because of its design, construction, location, atmosphere, or the materials or substances in it or other conditions.

**When assessing whether a space is or may become hazardous because of its atmosphere, a person may not take into account the use of PPE or ventilation as this can fail.

"External Service Provider (ESP)" — is an organization, corporation or person, who provides project or contracted services to Halifax Water in accordance with contract specifications, terms, and conditions.

"Lower Explosive Limit (LEL)" — means the lowest concentration (in air) of a gas or vapour that is needed for the gas to ignite.

"Supervisor" — any Halifax Water Employee who supervises or provides oversight of another Employee that enters Confined Spaces.

"Threshold Limit Values" — means the threshold limit values established by the TLVs and BEIs that represent:

- chemical substances, the airborne concentrations of chemical substances and conditions under which it is believed that nearly all healthy workers may be repeatedly exposed, day after day, over a working lifetime, without adverse health effects;
- for physical agents, the levels of exposure and conditions under which it is believed that nearly all healthy workers may be repeatedly exposed, day after day, without adverse health effects.

"TLVs and BEIs" — means the latest version of the publication of the American Conference of Governmental Industrial Hygienists of threshold limit values and biological exposure indices.

"Upper Explosive Limit (UEL)" — means the highest concentration (in air) of a gas or vapour that is needed for the gas to ignite.

Responsibilities of the Employees

Employees must follow this procedure and communicate safety or procedural deficiencies encountered in the field to their Supervisor. All Halifax Water Employees shall attend equipment training exercises as directed by their Supervisor so as to ensure their familiarity with the safe operation of gas monitoring equipment used by Halifax Water.

Responsibilities of External Service Providers

ESP's must provide valid gas monitors along with manufacturer specific training. Monitors must be capable of testing at minimum Lower Explosive Limit, Oxygen, Hydrogen Sulphide, and Carbon Monoxide.

27.04 Roles and Responsibilities

Responsibilities of the Supervisor

Supervisors must ensure that the standards required by this procedure are followed at all times when using gas monitors. Supervisors are directly responsible for ensuring the health and safety of Employees under their supervision in the workplace. Supervisor shall ensure that all Employees under their control are adequately trained to operate gas monitoring equipment and understand the requirements of this procedure. A monthly review of alarms recorded in the DS2 docking station server should be completed.

These responsibilities may be delegated to another designated competent person provided he/she is trained and qualified in all aspects of this procedure.

27.05 Implementation and Maintenance

Calibration of Testing Equipment

- All monitoring equipment shall be calibrated according to the frequency specified in the manufacturer's instructions or no more than once every 30 days.
- All monitoring equipment must be bump tested to a zero reading, as required by manufacturers' instructions prior to use.
- All failures of either bump test or calibration should be reported to your Supervisor.
- If Employees note issues with their gas monitor or the calibration gasses are low in the docking stations, they must notify their Supervisor who must arrange repairs.

Short Term Exposure Limit (STEL)

Short Term Exposure Limit (STEL) is defined by ACGIH as the concentration to which workers can be exposed continuously for a short period of time without suffering from:

- irritation
- chronic or irreversible tissue damage
- narcosis of sufficient degree to increase the likelihood of accidental injury, impair self-rescue or materially reduce work efficiency.

STEL's are generally used only when toxic effects have been reported from high acute (short-term) exposures in either humans or animals. A (STEL) is not a separate independent exposure limit, but supplements time-weighted average limits where there are recognized acute effects from a substance whose toxic effects generally chronic (long-term) in nature. For example, one cannot be exposed to a STEL concentration if the TLV-TWA (time weighted average) for an 8 hour shift would be exceeded. Workers can be exposed to a maximum of four STEL periods per 8 hour shift, with at least 60 minutes between exposure periods.

Time Weighted Averages (TWA)

Time Weighted Averages (TWA) are an average value of exposure over the course of an 8 hour work shift.

TWA levels are usually lower than ceiling values. Thus, a worker may be exposed to a level higher than the TWA for part of the day (but still lower than the ceiling value) as long as he/she is exposed to levels below the TWA for the rest of the day.

Most current testing devices have a built in means for calculating the TWA. The operator will need to consult the operating instructions for the particular device and need to understand why TWA is important to prevent over exposure to a person to a potentially toxic atmosphere and to determine when it is not safe to enter or continue to work in such atmospheres.

Threshold Alarms

Gas		Low Alarm	High Alarm
Carbon Monoxide	Above:	25	50
Oxygen	Below:	19.5	22.5
LEL	Above:	10	20
H_2S	Above:	3	5

Testing for Lower Explosive Limits (LEL)

- Halifax Water Employees shall not enter any space for any purpose at any time the atmosphere has been tested at more than 10% of LEL.
- When such results are obtained Employee will notify their Supervisor and inform them of the situation.
- Combustible, flammable or explosive atmospheres may and often exist together with toxic or oxygen deficient atmospheres.
- Combustible or flammable atmospheres are generally caused by:
  - evaporation of flammable liquids that have accidentally spilled or leaked into the infrastructure or illegally dumped (e.g., gasoline, solvents or other motor fuels)
  - by-products of chemical reactions (e.g., decomposition of organic matter, dead biologicals to form methane).
  - vapour releasing from Volatile Organic Compounds
  - Infiltration of Natural Gas from a leaking natural gas line.
- The elimination or control of all potential ignition sources is vital when combustible gases are detected at any level.

Always follow the instructions and warnings provided by the manufacturer of the detection device.

Testing for Oxygen (O2)

- Oxygen content above 22.5% can cause explosions or vigorous burning of flammable or reactive materials, including your hair or clothing.
- If oxygen content is less than 19.5% or greater than 22.5%, exit the space and contact your Supervisor.
- Oxygen meters may be adversely affected by high relative humidity, refer to manufacturers' instructions.
- When checking for oxygen in moist atmospheres, keep the probe pointed downward and wipe any water droplets from the probe should they develop.

Testing for Hydrogen Sulfide (H2S)

- This gas is highly toxic, corrosive and flammable and may be found in any Halifax Water worksite.
- Hydrogen sulfide may be present where there are any connections to a live sewer or where any organic material is decaying.
- This gas will be released anytime sediment or liquid containing the material is disturbed.
- H_2S greater than **3** ppm will require immediate evacuation of the space by staff.

Testing for Carbon Monoxide (CO)

- The maximum allowable Threshold Limit Value for carbon monoxide exposure shall not exceed 25ppm for a time weighted average of 8 hours.
- Staff shall evacuate the worksite immediately if the carbon monoxide tests at 25 ppm or more.
- Carbon Monoxide is a tasteless and odorless gas which is a result of incomplete combustion of hydrocarbon products such as propane, kerosene, diesel and other automotive fuels.
- Carbon monoxide has been known to be trapped in rock fissures for weeks following the detonation of explosives.
- This gas is classed as an asphyxiate which means it has the ability to block oxygen from being absorbed by the blood stream.
- This gas has the same density of normal air and can be found at any level.
- Cartridge respirators cannot be used for protection under any circumstances, adequate ventilation and dilution of the atmosphere must be maintained.
- Symptoms include fatigue, flu like symptoms, and impairment of motor functions.

Confined Spaces

H_2S is among the most common hazards found in confined spaces, especially in the oil industry and in waste and water treatment systems. Because H_2S is heavier than air, oxygen levels need to be tested as well as H_2S.

When should Atmospheric testing happen:

- When initially identifying a space
- Again before entering the confined space
- For the duration of the time work is being completed in that space (at least hourly for permit spaces; more often as warranted)
- Anytime work has ceased and then started up again

Alll evaluations and interpretations of the resultant data should be completed, or reviewed, by a technically qualified profession

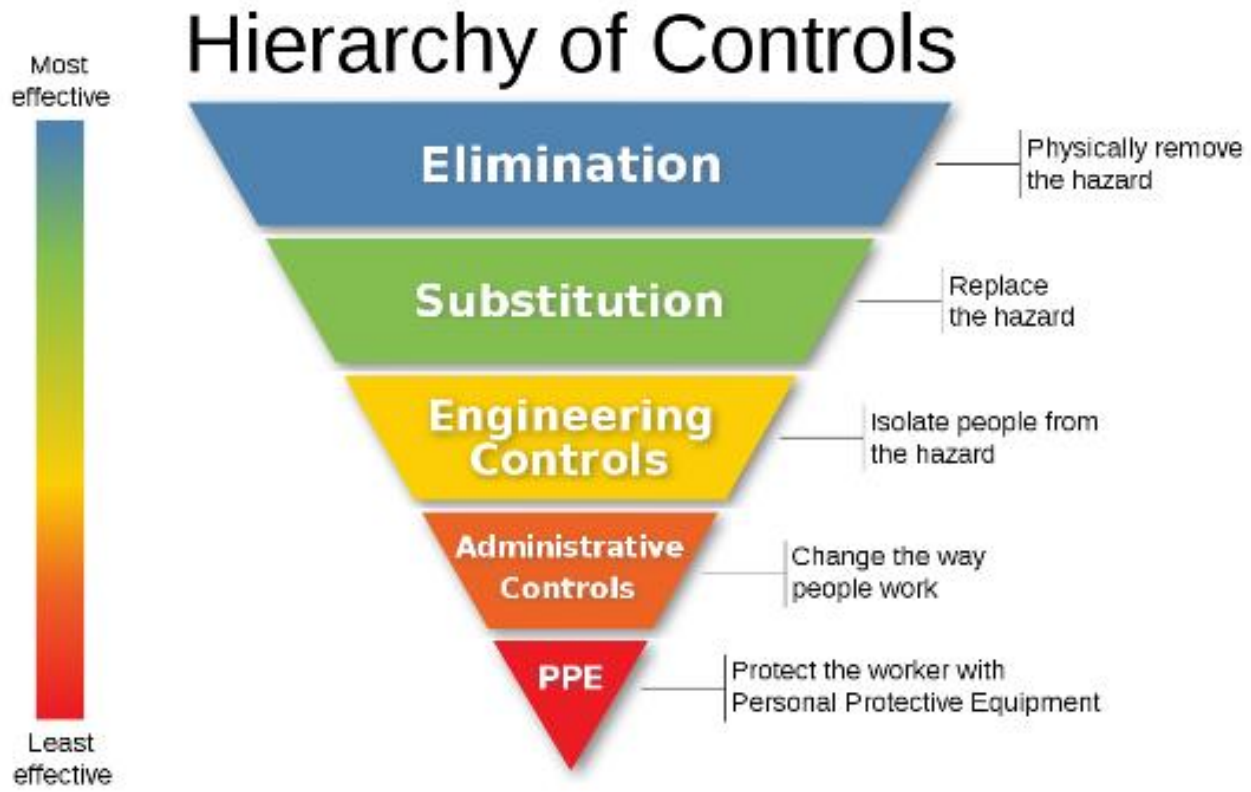
Confined Space Permits

Follow all Halifax Water Confined Space Entry Procedures and Entry Permits.

Practices/ Procedures

HAZARDOUS SPACES PROCEDURE	DESCRIPTION
General Safety Measures	• Supervisor must determine if a space is considered hazardous prior to work being conducted. • If the space is considered to be hazardous then it must be labeled a hazardous space. • Underground control chambers must be tested at 3 levels. The air quality can be measured using a gas meter equipped with an aspirated pump and tubing. Test the air for 2 minutes plus 2 seconds per foot of tubing. Test at 3 depths: top, middle and bottom of chamber and record readings on the log sheet. • An SOP will be developed to follow while performing work in that particular hazardous space. • Follow Gas Monitoring Procedure, Section 27.
Entering a Hazardous Space	Employees must be equipped with personal gas monitor before entering a hazardous space.

H2S Safe Work Practices



The hierarchy of controls is a system that shows you the best ways to remove or protect workers from hazards on jobsites. The process goes as follows:

- Elimination
- Substitution
- Engineering Controls
- Administrative Controls
- PPE

Elimination/Substitution

If possible, eliminate H_2S from your facility. Use other agents in replacement of it, if they are available. Understandably, H_2S is often a necessary evil. In these situations, other controls should be implemented to keep workers safe.

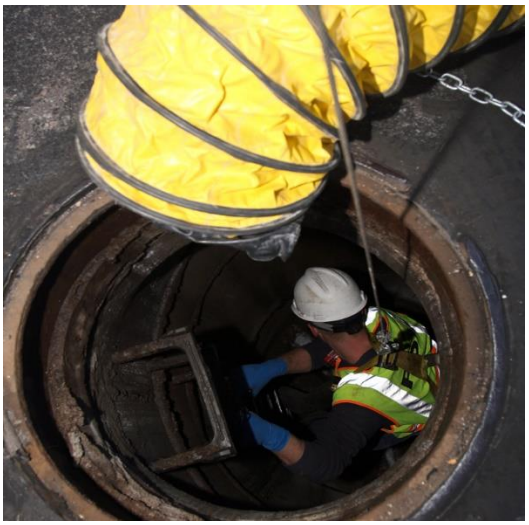
Engineering Controls

For many industries, H_2S is an inevitable hazard that cannot be eliminated or substituted. It is vital that employers make it safe for their employees to perform work. Engineering controls should eliminate or at least decrease the chances of employees coming in contact with H_2S. Areas that might have H_2S present should be as isolated as reasonably possible. Isolation methods can include fences, walls, and blocked entries.

When choosing how to isolate and area, care should be taken to avoid increasing concentrations by limiting the area's ventilation.

Employers should ensure that the integrity of any pipes, valves, storage tanks, or other equipment meant to handle or store H_2S is well maintained and in good condition. This will reduce the risk of employees being exposed to H_2S. Any equipment that is used for operations involving H_2S must be inspected and repaired routinely.

Pipes, storage containers, and any other equipment where H_2S is or might be present should be clearly marked with appropriate warning labels and signs. Make sure that the sign identifies the risk that H_2S poses to life.



Installing exhaust and ventilation systems in areas with H_2S is an effective way to reduce concentration of the gas. Ventilation should run continuously while work is being done in confined spaces.

Ventilation and exhaust systems that operate around H_2S need to possess certain qualities due to the nature of the gas. Each system needs to be:

- Resistant to corrosion
- Explosion-proof
- Non-sparking
- Grounded
- Separate from other ventilation systems

Administrative Controls

Administrative controls can help employees avoid exposure. Generally speaking, these will be established according to regulation, but administration should make sure that they are familiar with these policies and how they apply to the workplace.

There must be at least one attendant on each PRCS team, and that attendant must be present outside the space during entry. It is easy to fall into the trap of thinking the attendant assignment is just a “hole watch” with low-grade responsibilities. However, the reality is that the attendant has more duties listed than any other team member. No matter your assignment in confined space operations, no job—no matter how small or seemingly insignificant—should be taken lightly.

The attendant must:

- Know the hazards faced during entry, including information on the mode, signs, symptoms, and consequences of exposure to those hazards
- Know how to monitor atmospheric conditions prior to and during entry and properly record the data
- Know how to monitor possible behavioral effects of hazard exposure for the authorized entrants
- Control access to the space and keep count of entrants
- Remain outside the space until relieved by another qualified attendant
- Communicate with entrants throughout their work
- Monitor and evacuate entrants, if necessary
- Summon rescue help, if needed
- Warn unauthorized persons
- Be able to perform non-entry rescues

Additionally, the attendant cannot perform any other duties that may interfere with these primary tasks. Similarly to confined space entry, establishing a buddy system on your worksite will facilitate quick responses in case there is an emergency. Having a worker who can watch another employee while performing a task that might lead to H_2S exposure will ensure that someone is able to call emergency rescue if that worker goes down.

It's best practice to train all workers on what to do if another worker is exposed to H_2S. This allows workers to rotate jobs when needed. Before workers are prepared to attend, they must be trained on:

- Who to call in case of emergency
- What information rescue teams will need
- Ways to prepare for rescue extraction

Perhaps one of the most difficult things that all workers need to understand is not to attempt to rescue another coworker that has been rendered unconscious in a confined space or hazardous area. Whether by H_2S or another hazard, workers cannot enter the space to perform a rescue unless they are thoroughly trained and have the proper equipment. Statistics show that approximately 40 percent of confined space fatalities are would-be rescuers.

When a coworker goes down in a hazardous area, the instinct to save him can be overwhelming. Even when trained not to attempt a rescue, workers will often forget themselves in such situations. Training workers to perform emergency rescues and giving them the proper equipment to do so in areas with high levels of H_2S gas may not only save the life of workers who have been exposed to the gas, but also the would-be rescuers.

Establishing procedures for preventing exposure and leaks will prevent H_2S from escaping. This should include frequent testing of equipment and inspections of pipes, containers, and other sources of H_2S with damage, wear, or potential for release of H_2S.

Procedures for hot work should be established for operations where there is a risk of H_2S exposure. Testing for explosive gases must take place before performing any welding, cutting, or other type of hot work. Similar precautions should be taken in areas prone to H_2S exposure and l

When H_2S reaches certain concentrations that exceed the acceptable ceiling limit, it can be very explosive and deadly. When abundant amounts of H_2S are present, a single spark can ignite it. Special tools and equipment that will prevent sparking need to be used in these situations.

Accidental Release Measures for H2S

- **What are accidental release measures for hydrogen sulfide?**
- **Personal Precautions:** Evacuate the area immediately. Isolate the hazard area. Keep out unnecessary and unprotected personnel. Evacuate downwind locations. Do not touch damaged containers or spilled product unless wearing appropriate protective equipment. Ventilate area. Eliminate all ignition sources. Use grounded, explosion-proof equipment. Distant ignition and flashback are possible.
- **Methods for Containment and Clean-up:** Liquid: stop or reduce leak if safe to do so. If not, allow liquid to vapourize. Ventilate the area to prevent the gas from accumulating, especially in confined spaces. Gas: stop or reduce leak if safe to do so. Ventilate the area to prevent the gas from accumulating, especially in confined spaces.

Personal Protective Equipment for H2S

Regulations allow various respirators be used to guard against H_2S in concentrations up to 100 PPM. These include powered and unpowered air-purifying respirators with cartridges that protect against gas. Additionally, any air-supplied or self-contained breathing apparatuses may be used. Due to the damage that can be inflicted on the eyes at this concentration of H_2S, it is highly recommended that workers wear full face-piece respirators.

Respirators

Personal respirators are just as important. In fact, whenever regulating measures are not adequate to inhibit atmospheric contamination employees are required to wear personal respirators. Moreover, regulations require that the employer must provide the correct type of respirator for the substance and level of exposure involved. There are two main types of respirators used for areas with H2S: Air-Purifying & Air-Supplying

Air-Purifying Respirator

Air-purifying respirators use filters to remove harmful substances from the air. They do not supply oxygen; instead, they filter the existing air. For this reason, they must never be used in oxygen-deficient atmospheres or in other atmospheres that are immediately dangerous to life or health (IDLH). Any concentration of H_2S that is 100 ppm or higher is considered IDLH.

Filtering Facepiece Respirators

Photo courtesy of Shutterstock

Filtering facepiece respirators (FFRs) remove particles from the inhaled airstream of the wearer. They may be referred to as "N95 respirators". They are also sometimes called disposable respirators because the entire respirator is discarded when it becomes unsuitable for further use because of hygiene, excessive resistance, or physical damage.

FFRs are divided into classes based on their filtration capabilities. "N95" is a term referring to the N95 filter class, which removes at least 95% of airborne particles using a "most-penetrating" sized particle during "worst case" NIOSH testing. The FFR classes include N (not resistant to oil), R (somewhat resistant to oil), and P (strongly resistant to oil) series, which are available at 95, 99, and 100 filtration efficiency levels.

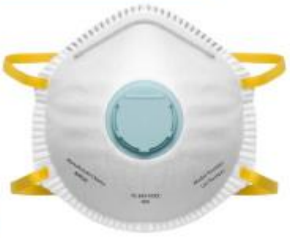
FFRs provide protection against particles, but not gases or vapors, and should not be used for respiratory protection to protect against hazardous gases or vapors. These classes and oil-resistant designations are applicable to all types of air-purifying respirators.

N95, N99, N100 – Filters at least 95%, 99%, 99.97% of airborne particles. Not resistant to oil.

R95, R99, R100 – Filters at least 95%, 99%, 99.97% of airborne particles. Somewhat resistant to oil.

P95, P99, P100 – Filters at least 95%, 99%, 99.97% of airborne particles. Strongly resistant to oil.

FFRs form a tight seal against the user's face, covering the nose and mouth. As the user inhales air through the facepiece, particulate material collects on the fibrous material of the filter, which removes the particulate contaminant from the airstream. An FFR may have an exhalation valve located on the filter, which reduces breathing resistance during exhalation.



When an air-purifying respirator is selected for protection against gases and vapors, a mechanism must be in place that will dependably warn wearers of a contaminant breach. These systems can be: a respirator equipped with an end-of-service life indicator (ESLI) certified by NIOSH for the contaminant, or a reputable and required cartridge change schedule that is based on objective information that will ensure that canisters and cartridges are changed before the end of their service life.

Working with H_2S at concentrations lower than 100 ppm requires a powered air-purifying respirator or an air-purifying, full face-piece respirator with the appropriate cartridge for your protection. Any supplied-air respirator (or SCBA) will also do. Wearing a full face-piece respirator is recommended, as it will also protect your eyes.

Remember it is Halifax Water policy to shut down the jobsite if the H2S concentration goes above 5 ppm

Inspection

Regardless of the respirator, it is vital that you inspect yours for wear and tear before *and* after each use, paying specific attention to any rubber or plastic parts that can easily deteriorate. The face piece, headband, valves, connecting tube, fittings, and cartridges/filters must be in good condition. A respirator inspection must include a check for tightness of attachments. Replace chemical cartridges and canisters as necessary, and replace mechanical filters as needed to avoid experiencing breathing difficulties.

Only an experienced person is permitted to make repairs, using parts specifically designed for the respirator. This person must consult the manufacturer's instructions for any repair, and no attempt should be made to repair or replace components outside the manufacturer's recommendations. Employers must keep records of inspection dates and findings.

Cleaning And Storage

After use, respirators should be cleaned and disinfected as necessary, especially if they were used in an emergency rescue situation. At the very least, they should be wiped down with a manufacturer-approved respirator refresher wipe. This will help keep bacteria, fungus, etc. at bay. There are many instances when a worker's failure to consistently clean his respirator led to prolonged illness and discomfort.

Outside of a general cleaning, a deep cleaning is not only wise but required, especially as it concerns the changing of the cartridges. While there are general guidelines for cleaning, you should strictly follow the manufacturer's schedule regarding when and how your type of respirator should be taken apart and cleaned. Deep cleaning should include a thorough washing of any and all straps, valves, hoses, diaphragms, seals, face shields, etc.

Once cleaned and allowed to dry completely, new cartridges should be installed, and the respirator should be stored in a way that guards it against dust, sunlight, extreme temperatures, excessive moisture, or any detrimental chemicals. Consider hanging it in a clean location, like a locker designated for such a purpose, or placing it an approved sealable bag. When packed or stored, make sure each respirator is positioned so as to allow it to maintain its natural shape and formation. This will prevent the rubber or plastic from deforming and cracking.

Fit Test

An ill-fitting mask won't do you any good. Contaminated air leaking in in any degree could prove fatal. This process is called a "fit test." A fit test tests the seal between the face piece and your face. It can take about 20 minutes to complete and should be performed *at least* annually. This can be done by your employer or by a third party.

You should be tested for the exact make, model, style and size of respirator you will be using.

Also, many workers wear prescription glasses or are required to wear personal protective equipment while working (goggles, ear muffs, etc.). If this describes you, then make sure you are wearing these items during the fit test.

Once you've passed the fit test, you must use that specific make, model, style and size of respirator every time. If it becomes damaged; the job changes, thus requiring a different kind; or you are assigned a different kind, you must be fit tested again. The same goes for whenever there is a change significant enough to alter your physical condition:

- Large weight gain or loss
- Major dental work or a change in dentures
- Facial surgery
- Significant scarring
- Changes in hairstyle or facial hair (facial hair should never be where the mask seals to the face)

Fit test records must be retained until the next evaluations or tests are administered.

User Seal Check

A fit test should not be confused with a user seal check. A user seal check is a quick check performed by the wearer *each time* the respirator is put on. It determines if the respirator is properly seated to the face or needs to be readjusted. It is important that you understand "user seal checks" are never substitutes for qualitative or quantitative fit tests.

Safety Equipment

Wearing fall protection gear while in areas with H_2S hazards can be lifesaving. The gas has the ability to render you unconscious, even instantaneously in the right concentrations. If you are climbing a ladder or are otherwise high up when the gas affects you, your fall could be deadly without the right protection.

When working in spaces that may contain H_2S, certain equipment might be necessary. When worn, this equipment will allow for a non-entry emergency rescue. Such equipment can include but is not limited to:

- Body harnesses
- Lanyards
- Tripods
- Ropes and cables

Safety equipment should be inspected before and after each use. If there are any tears, frays, cuts, or other damage on the equipment, it must be taken out of service immediately. Workers should be trained on how to thoroughly check all equipment before use.

H2S Hazards

H_2S is among the most dangerous substances workers are exposed to on their sites. Comparable to hydrogen cyanide, the gas used in mass executions during WWII, H_2S is over five times more deadly than carbon monoxide.

Accident Profile #1: Three sewage workers were performing maintenance on a 24ft (7.3 m) deep wet well. Employee #1 was attempting to dislodge a rubber plug from a sewer pipe within the well while Employees #1 and #2 were pulling on the plug from above. After some difficulty removing the plug, Employee #1 began ascending the ladder when he suddenly lost consciousness and fell to the bottom. Employee #2 began descending the latter when he, too, fell unconscious. In an attempt to rescue his fellow coworkers, Employee #3 attempted to descend and provide emergency rescue, but was also rendered unconscious. All three workers died from asphyxiation. **What went wrong?**

All three employees died from exposure to H_2S gas. No atmospheric testing had been done prior to entry. Before entering any confined space, atmospheric testing should be performed. If done properly, the testing would have alerted the workers to the H_2S that was present in the well, likely saving all three of their lives.

What made this event even more tragic were the deaths of the two would-be rescuers. Although it might be hard to watch a fellow worker lie unconscious, rushing in to save him will only put you in danger. You will more than likely succumb to the same hazards and have to be rescued as well, thus prolonging the rescue of your coworker. Calling for help, testing the atmospheric conditions, and preparing for the rescue team will do more to save your friend than attempting to rescue him yourself.

Never enter a confined space without testing it first. If there is H_2S gas present, make sure to use ventilation before entry to reduce the concentration to acceptable levels. Make sure that you wear the respirators and PPE necessary to protect yourself. Never enter a confined space to perform a rescue without proper training, equipment, and support.

Accident Profile #2: Employees #1 and #2 entered a 10-foot manhole to secure a leaking air plug. Employee #2 descended the manhole ladder and was overcome by hydrogen sulfide, falling approximately five feet to the bottom of the manhole. The manhole attendant screamed for help as Employee #1 descended the ladder in an attempt of rescue unconscious Employee #2. Employee #1 was promptly overcome by hydrogen sulfide, lost consciousness, and followed his coworker to the bottom of the ditch. The excavator operator called Emergency Services and prevented any more workers from entering the manhole. He then directed air from a compressor into the crevice, which allowed both employees to regain consciousness. Finally, a strap was lowered into the hole to help the employees escape. **What went wrong?**

Both employees were exposed to high levels of H_2S. Again, no atmospheric testing or monitoring took place prior to entry to the confined space. Whenever entering a confined space, pre-atmospheric testing and monitoring must be conducted.

Although the workers were entering a deep manhole, no fall protection was offered to them before they descended. When possible, having attached lifelines, lanyards, or other forms of fall protection and retrieval systems can help prevent injuries and falls during exposure and may offer a safe rescue from outside the space. The excavator operator responded appropriately by preventing other workers from entering the space by using ventilation to bring fresh air to the unconscious employees without exposing anyone else to the hazards. This, coupled with the safety strap, likely saved the lives of the two men in the manhole.

Accident Profile #3 While working inside a 27ft (8.2m) excavation pit, workers noticed a noxious gas smell. Concerned about both the gas and the integrity of the pit, the foreman had all his workers evacuate the area. Employee #1 reentered the pit to retrieve a tool and was overcome by the gas. In an attempt to save the worker, a police officer followed him in. Suddenly feeling ill, the officer began climbing back up the ladder, but fell to the bottom of the pit, which was flowing with water. Though he attempted to climb out of the water, the officer only rolled over and drowned. **What went wrong?**

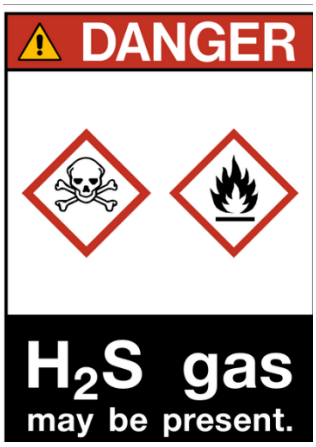
There were several things wrong with this scenario, the first being a lack of training of employees. Workers were made aware of the potential existence of gas, but delayed leaving the excavation site when they noticed signs of its presence. The general lack of communication between the crew and emergency responders made the would-be rescuer unaware of the toxic gas. As a first responder, the police officer was trained to perform an emergency extraction, and he entered the pit without protective gear. Training workers on the nature and dangers of H_2S and what to do in emergency situations will prevent future tragic outcomes like these from occurring.

The crew was warned beforehand of the potential presence of H_2S, which was common in the marshy area where they were located. Workers noticed the scent of H_2S and immediately felt short of breath, sending two employees out for blowers to ventilate the pit. In the meantime, the crew remained in the area, operating without ventilation. No atmospheric monitoring was performed, despite the knowledge of potential hazards. All of this oversight contributed to the death of the officer, as well as serious injury to multiple members of the crew.

Accident Profile #4: Employee #1 entered a manure pit to replace a broken line. Despite warnings, he had worked in the pit before without issue and insisted that he would be ok. As he was tying the line, he suddenly fell unconscious. Employee #2, who had warned Employee #1 previously, called in the accident. Responding to the call, Employee #3 arrived on scene. Despite warnings from Employee #2, Employee #3 entered the pit to tie a line to Employee #1, but also fell unconscious. Rescue teams arrived with SCBAs and retrieved the two victims. Both were pronounced dead at the hospital. The cause of death was asphyxiation by H_2S. **What went wrong?**

Employee #1 should have never entered the pit without testing or proper safety equipment. Even if you have worked around H_2S before without issue, you should know that toxic fumes can still form under the right conditions. In this case, H_2S formed in the pit and rendered Employee #1 unconscious. Employee #3 attempted to rescue Employee #1 without protection and, in turn, put his own life in danger.

Fire Hazards and Extinguishing Media for H2S



- **What are fire hazards and extinguishing media for hydrogen sulfide?**
- **Flammable Properties:** EXTREMELY FLAMMABLE GAS. Can easily ignite. Can readily form explosive mixture with air at room temperature.
- **Suitable Extinguishing Media:** Carbon dioxide, dry chemical powder, water spray or fog.
- **Specific Hazards Arising from the Chemical:** Gas may travel a considerable distance to a source of ignition and flash back to a leak or open container. Gas may accumulate in hazardous amounts in low-lying areas especially inside confined spaces, resulting in a health hazard. Heat from fire can cause a rapid build-up of pressure inside cylinders. Explosive rupture and a sudden release of large amounts of gas may result. Cylinder may also rocket. In a fire, the following hazardous materials may be generated:
- corrosive sulfur oxides.

Stability and Reactivity Hazards of Hydrogen Sulfide

- **What are the stability and reactivity hazards of hydrogen sulfide?**
- **Chemical Stability:** Normally stable.
- **Conditions to Avoid:** Open flames, sparks, static discharge, heat and other ignition sources.
- **Incompatible Materials:** Highly reactive. Increased risk of fire and explosion on contact with: metal oxides (e.g. copper oxide), oxidizing agents (e.g. peroxides), strong bases (e.g. sodium hydroxide). In the presence of water, corrosive to: carbon steel. Not corrosive to: aluminum alloys.
- **Hazardous Decomposition Products:** None known.

Possibility of Hazardous Reactions: None known.

Conclusion

When working with H2S, you can help ensure safe operations by knowing and following all safe work practices and safety regulations applicable to your workplace. When in doubt during any phase of an operation, take the time to stop and consult your employer, the standards, and/or equipment manufacturers. Time is money, true, but a mistake made to save time can cost money, and even lives!