Other Hazardous Gas

Acid Fumes

Skin reddens and blisters when exposed to acid fumes. When inhaled, a sore throat and shortness of breath result. Severe exposure can cause pulmonary oedema with a potentially fatal result when fluid accumulates in the lungs.

CASE STUDY

Lung injury from cleaning with acid in a tank

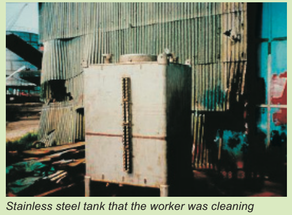
A worker experienced breathing difficulties and chest pain after cleaning the interior of a stainless steel tank with hydrochloric acid. He was later diagnosed to be suffering from pulmonary oedema as a result of breathing in acid fumes while working in the confined space.

Investigations revealed:

- forced ventilation was not provided.
- the organic vapour respirator worn by the worker was not suitable for acidic fumes.
- there were no safe work procedures for the usage of acids and for entry into and working in a confined space.
- assessments were not conducted to ensure that cleaning does not create a hazardous environment inside a confined space.
- safety precautions were not taken to control hazards.

Systemic failures:

The lack of safe work practices and hazard analysis.



Stainless steel tank that the worker was cleaning

Incorrect respirators that do not protect against acid mists were used by the worker

Control and Preventive Measures

The following measures should be taken where appropriate to prevent deaths and injuries from confined space work.

Risk assessment

Prior to commencement of work, a risk assessment must be carried out to identify the hazards associated with the work, assess the risk of accident that may occur, implement safe work procedures and take appropriate measures to eliminate the hazards, or to reduce the risk.

Isolation

Before entry, valves and pumps to all pipes leading to confined spaces must be locked and tagged to prevent the entry of hazardous materials.

Gas check

A competent person must test and certify the atmosphere of confined spaces for oxygen, flammable and toxic gases or vapours prior to entry. Confined spaces can only be certified safe for entry if:

- the oxygen level is within 19.5% to 23.5%;
- the level of flammable gas is less than 10% of the Lower Exposure Limit (LEL); and
- the concentration of toxic gases or vapours is below the Permissible Exposure Level (PEL).

While a person is inside the space, continuous or regular gas testing should be conducted to ensure that the space remains safe.

Calibration of gas meters

It is important that gas monitoring devices are regularly maintained and their accuracy verified with functional (bump) tests and full calibrations.

A functional test is a brief exposure of the gas monitor to a known gas for the purpose of verifying sensor and alarm operation. If the instrument fails to operate properly following any functional test, a full instrument calibration should be performed.

A full calibration involves the use of (certified standard) calibration gases, and requires verification that the gas concentrations listed on the cylinder label match the concentration setting for calibration in the instrument. Calibrations must be carried out by trained personnel, and records kept.

Entry permit

Before entering a confined space, a permit must be issued by a competent person certifying that all hazards have been assessed and precautionary measures have been taken to ensure the safety of entrants.

Forced ventilation

When a confined space is occupied, an adequate and continuous supply of fresh air should be provided. This can be from air blowers with trunking or extension hoses.

Buddy system

A standby person should be stationed outside the confined space to keep a lookout and render help in the event of an emergency.

Safety appliances

When entering a confined space, a safety harness and lifeline should always be worn. This will facilitate retrieval during an emergency. Suitable respirators should be worn where toxic gases or vapours are known to be present. Air supplied respirators must be used if the space is likely to be deficient in oxygen or contains unknown or high concentrations of air contaminants.

Rescue equipment

On-site rescue equipment such as retrieval devices and breathing and reviving apparatus should be readily available for emergency use. The severity of accidents can be reduced with timely alerts from attendants outside the space and by having well-trained and fully equipped rescuers to ensure a speedy response in the event of an emergency.

Other safety measures

- Diesel-driven and petrol-driven engines such as pumps and compressors should never be placed inside a confined space.
- Host employers should ensure that contractors are competent for work involving a confined space. They also need to brief their contractors on any precautions or procedures to be implemented.
- Every supervisor and entrant must be familiar with the safe work procedures for entry into and work in a confined space. They should also be fully aware of the hazards associated with the confined space, and those that can be introduced into the space by their work.
- Procedures for emergency response must be established and communicated to all personnel onsite.

MINISTRY OF MANPOWER

SAFE & HEALTHY WORKPLACE

Contact Us

For more safety requirements on entry into and working in confined spaces, please refer to **Singapore Standard Code of Practice (CP) 84 Code of Practice for Entry Into and Safe Working in Confined Spaces**.

The CP can be obtained from SPRING Singapore at:
SPRING Singapore
Information Resource Centre
2 Bukit Merah Central
#04-00 S159835
Tel: (65) 6279 3920

The Workplace Safety and Health (General Provisions) and Workplace Safety and Health (Risk Management) Regulations are available at:
SNP Corporation (Legal) Ltd
Legal Publications Retail Outlet
1 Kim Seng Promenade #18-01/06
Great World City East Tower S237994
Tel: (65) 68269691
Website: http://www.snpcorp.com/webshop

For more information on Risk Assessment, Guidelines on Risk Assessment are available for download from MOM website at:
www.mom.gov.sg/oshd

For enquiry, please email us at:
mom_oshd@mom.gov.sg

To report unsafe workplaces, please call the OSH hotline at 6317 1111.

To report accidents, dangerous occurrences and occupational diseases visit
www.mom.gov.sg/ireport

National OSH PROGRAMME-BASED ENGAGEMENT (ProBE)

Technical Advisory for Confined Spaces

Confined spaces in the workplace include any chamber, tank, pit, pipe, flue or enclosed space in which either or both of the following situations are possible:

- Dangerous fumes are liable to be present to such an extent as to involve risk of fire or explosion, or persons being overcome by fumes.
- The supply of air is inadequate, or is likely to be reduced to be inadequate for sustaining life.

Hazards in confined spaces can be broadly separated into the following two categories:

Atmospheric hazards
e.g. oxygen deficiency and presence of toxic or flammable gases or vapours.

Physical hazards
e.g. slips and falls, moving machines, exposed electrical components, engulfment and drowning.

This advisory will focus on atmospheric hazards. Being invisible, their inherent dangers are often underestimated and can immediately incapacitate a person without warning.

Legislative requirements on confined space work

Safety measures for confined space work as required under Regulation 25 of the Workplace Safety and Health (General Provisions) Regulations include:

- removing any sludge or deposit liable to give off dangerous fumes before confined space entry
- preventing entry of dangerous fumes into the confined space
- adequately ventilating the space to sustain life before entry and during work
- competent testing of the space for oxygen and any flammable or toxic gases and vapours
- wearing suitable breathing apparatus if any space cannot be made safe for entry
- wearing a safety harness and lifeline where practicable, and having a standby person keeping watch from outside the space
- ensuring there is a sufficient supply of emergency response equipment such as breathing and reviving apparatus, belts and ropes
- having a sufficient number of employees trained and practised in the use of emergency response equipment, and in a method of restoring respiration

Under the Workplace Safety and Health (Risk Management) Regulations, every employer and contractor must conduct a risk assessment in relation to the safety and health risks posed to any person who may be affected by his undertaking, and take all reasonably practicable steps to eliminate any foreseeable risk.

In addition, safe work procedures must be implemented to control the risks. The safe work procedures must include the safety precautions to be taken in the event of an emergency. Employees or any other persons at the workplace who may be exposed to a risk to their safety and health must be informed of:

- the nature of the risk involved;
- the measures implemented to control the risk; and
- applicable safe work procedures.

Common Hazards and Case Studies

Oxygen Deficient Atmospheres

The level of oxygen inside a confined space can be reduced to a dangerous level due to:

- chemical reactions (rusting, decomposition and fermentation)
- absorption by porous materials (e.g. activated carbon)
- displacement by inert gases (e.g. nitrogen and carbon dioxide)

As oxygen is vital for sustaining life, many physiological effects emerge when the oxygen content is below the minimum safe level. The symptoms range from mild headache to permanent brain damage or death at a highly deficient level.

A confined space is permitted for entry if it contains at least 19.5% oxygen by volume.

CASE STUDY
Worker died during a visual inspection of a nitrogen-filled ISO tank
The last cargo carried was di-octylphthlate (DOP), and nitrogen was used as an expelling agent to unload the cargo. After unloading, the tank was still filled with nitrogen and was therefore highly deficient in oxygen when the victim entered to inspect its interior. He died from asphyxiation as a result.

Investigations revealed:

- the company had failed to implement safe work procedures and a permit-to-work system for confined space work.
- no suitable gas-testing meters were available onsite so the ISO tanks had not been tested and certified safe for entry.
- the victim had not been specifically trained in confined space work.
- prior to the accident, workers had not been using breathing apparatus or appointing safety attendants to keep watch.

Systemic failures:
The lack of safety policy, hazard analysis, safe work practices and safety training.

Picture of the ISO tank involved in accident

The manhole into the ISO tank

Toxic Atmospheres

Air contamination inside a confined space occurs when hazardous substances inside the space become airborne. Depending on the type of contaminants, the effects can be irritation, asphyxiation, or systemic poisoning, even at low concentrations.

Common toxic/poisonous gases:

- Solvent vapours (e.g. acetone, toluene, trichloroethylene, xylene)
- Carbon monoxide
- Hydrogen sulphide
- Petroleum vapours (e.g. naphtha)

Ensure that the concentrations of toxic gases or vapours in the confined space are below the Permissible Exposure Levels (PEL).

Useful points to note when assessing the conditions of a confined space:
1) Contents - Previous contents in the space
2) Reactions - Possible reactions that can happen inside
3) Operations - Nature and type of operations to be carried out inside, including the type of materials to be used
4) Potential hazards - Inadvertent introduction of contaminants from outside environment

Solvent Vapours

Solvents are petroleum derivatives and are commonly found in products such as paints, cleaning agents and adhesives. Due to their highly volatile nature, solvents can rapidly accumulate at dangerous levels in unventilated confined spaces. Acute exposure usually results in narcosis as many of the vapours depress brain function and the central nervous system. Chronic exposure can cause systemic poisoning and damage the organs.

CASE STUDY
Worker died while painting in a confined space
A worker died from excessive inhalation of solvents inside the leg compartment of a container crane while carrying out painting work on the welding seams inside the compartment.

Investigations revealed:

- mechanical ventilation had been provided but was found to be neither effective nor adequate. As a result, high concentrations of paint solvents released during the painting job accumulated in the compartment.
- the paint used was a mixture of paint base and curing agent. Analysis showed that the mixture contained xylene and n-butanol. It was estimated that at the time of the accident, the concentrations of xylene and n-butanol inside the compartment were more than 6,000 ppm and 2,000 ppm respectively. The Permissible Exposure Levels (Short Term) for xylene and n-butanol are 150 ppm and 50 ppm respectively.
- the cartridge filter of the respirator worn by the victim had already been saturated from a previous job, and with the large amount of vapour present in the confined space, an air-fed mask should have been used.

Systemic failures:
The lack of hazard analysis, safe work practices, and safety training.

Carbon Monoxide

Carbon monoxide is a colourless and odourless gas that is produced from incomplete combustion. The gas is a chemical asphyxiant. It binds strongly to red blood cells, preventing the flow of oxygen to the brain. In the absence of oxygen, the brain cells die, leading to unconsciousness and even death.

The Permissible Exposure Level (Long Term) for carbon monoxide is 25 ppm.

Posed picture showing how the worker entered the manhole

Position of the petrol-driven pump inside the manhole

CASE STUDY
Worker poisoned by fumes from a petrol-driven pump in a sewer manhole
A sanitation worker who had been tasked to oversee the pumping of water from a new sewer manhole died as a result of being overcome by poisonous carbon monoxide fumes and subsequently drowning.

Investigations revealed:

- that more than 11,000 ppm of carbon monoxide could have been present inside the manhole at the time of the accident.
- the build-up of carbon monoxide in the manhole was caused by the petrol-driven pump being operated in the confined space.
- mechanical ventilation was not provided and gas testing was not carried out before the victim entered the fume-filled manhole in an attempt to restart the pump that had stopped.
- there were serious lapses in the implementation of safe work procedures by both the main contractors and the sub-contractors.
- workers routinely entered confined spaces without adhering to proper safety procedures.

Systemic failures:
The lack of hazard analysis, safe work practices, management of sub-contractors, and inadequate safety training.

Hydrogen Sulphide

Hydrogen sulphide is a rapidly acting systemic poison which, at high concentrations, paralyses the respiratory function and causes asphyxiation. When breathed in for prolonged periods at low concentrations, it dulls the sense of its characteristic rotten-egg odour. At high concentrations, the sense of smell is readily deadened, so odour cannot be used as an early warning sign.

The Permissible Exposure Level for hydrogen sulphide is 15 ppm (Short Term), and 10ppm (Long Term).

CASE STUDY
Two killed and one injured by hydrogen sulphide
While clearing a sewage blockage in a manhole, a worker was overcome by hydrogen sulphide and collapsed. His supervisor and a passerby, in an attempt to rescue him, entered the confined space without following proper emergency procedures. As a result of poisoning by hydrogen sulphide, the supervisor died while the worker and the passerby recovered.

Investigations revealed:

- hydrogen sulphide trapped within the decomposed sewage was released when the sewer was dislodged.
- the toxic gas was present in a significant quantity to cause the victims to collapse inside the manhole.
- there was 36 ppm of hydrogen sulphide inside the manhole at the time of the investigation. The actual concentration at the time of the accident could have been very much higher.
- the sub-contractor had failed to identify the possibility of hydrogen sulphide release when carrying out sanitary maintenance in the sewer.
- the manhole had not been certified safe for entry and had not been ventilated.
- workers were not instructed to use breathing apparatus or wear a proper safety belt with lifeline attached for work inside the confined space.

Systemic failures:
The lack of hazard analysis, safe work procedures, and management of sub-contractors.

Conditions inside the sewer manhole

Petroleum Vapours

Petroleum is made up of a complex mixture of volatile hydrocarbons. In addition to being flammable, petroleum vapours can affect health depending on the degree of exposure. The effects range from eye and skin irritation to narcosis of the central nervous system. Exposure to high concentrations of such vapours can result in loss of consciousness and death.

Area where the victim was working when the accident occurred

Residual discharge from an open pipe at the accident site

CASE STUDY
Marine pipe fitter died after inhaling naphtha fumes
A worker was found dead at the bilge of a pump room on board a vessel under repair at a shipyard. He had been overcome by petroleum vapours while cleaning the flanges of dismantled pipes. Some fluid was observed leaking from the open pipes nearby.

Investigations revealed:

- the fluid to be naphtha, which was the last cargo carried by the vessel.
- the contractor had failed to ensure that the dismantled pipes were blanked off to prevent discharge of residual cargo from the pipes.
- there was a lapse in performing the scheduled gas testing.
- hydrocarbon vapour concentrations in the pump room indicated the presence of approximately 2,000 ppm of naphtha vapours. The Permissible Exposure Level (Long Term) for naphtha is 300 ppm.
- the victim did not carry any monitoring device that would have alerted him of the dangerous levels of atmospheric contaminants.
- ventilation provided was inadequate, causing a build-up of vapours in the confined space.

Systemic failures:
The lack of hazard analysis, safe work procedures and control of hazardous substances.

Flammable Atmospheres

Flammable substances in a confined space can cause fire and explosions in the presence of an ignition source e.g. open flame and sparks. Flammable sources include:

- residual gases or vapours e.g. petroleum vapours
- leaks from gas cylinders or pipelines e.g. acetylene, liquefied petroleum or natural gas
- underground marsh gas (methane)
- vapours evaporated from solvents e.g. toluene, xylene

Flammable gases or vapours are ignitable only if their concentrations are within the flammable range. The boundaries of this range are set by two specific levels known as the Lower Explosive Limit (LEL) and Upper Explosive Limit (UEL).

The concentration of any flammable gas or vapour in a confined space must not be more than 10% LEL.

If hot works is to be carried out in the space, the space should be free from any flammable substance.

CASE STUDY
One worker died and another was injured in a flash fire onboard a ship
A flash fire in a ballast tank onboard a tanker under repair caused the death of one worker and injured another. The two workers were repairing a faulty pneumatic pump in the tank when the flash fire occurred.

Investigations revealed:

- high levels of flammable hydrocarbons were found in the tank.
- the source of the flammable substance was likely to be naphtha, the tanker's previous cargo. This may have leaked out from one of the cargo tanks into the ballast tank.
- As the lighting used was of the non-flame proof type, it could have ignited the flammable vapours inside the tank, resulting in the flash fire.

Systemic failures:
The lack of hazard analysis, and safe work practices.